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AFATL-TR-72-174

**OPERATING CHARACTERISTIC CURVES
FOR
SAMPLES FROM A BINOMIAL POPULATION**

PRODUCT ASSURANCE DIVISION

TECHNICAL REPORT AFATL-TR-72-174

AUGUST 1972

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B

Operating Characteristic Curves
for
Samples from a Binomial Population

Mark O. Glasgow
Russell R. Ratcliff

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this document must be referred to the Air Force Armament
Laboratory (DLGZ), Eglin Air Force Base, Florida 32542.

FOREWORD

The work reported in this technical report was undertaken in support of reliability and quality assurance functions and was done during the period October 1971 to July 1972.

Digital computer services in support of this effort were provided by the Computer Sciences Laboratory (TSX), Eglin Air Force Base, Florida.

Significant assistance in the preparation of this report was provided by the members of the Reliability Engineering and Quality Assurance Branch (DLGR). A special acknowledgement is due to Mr. Thomas J. Psaltis of the Weapons Support Branch (TSXBW) and particularly to Mr. Cecil D. Cliburn (TSXBW) for programming the computations.

This technical report has been reviewed and is approved.


RANDALL L. FETTY, Colonel, USAF
Chief, Product Assurance Division

ABSTRACT

Operating characteristic curves are presented which give the probability of a random sample from a binomial population being accepted versus the true reliability of the lot for a given sample size and with the acceptance number of defectives held fast. The curves can be used by statisticians, engineers, and quality assurance workers concerned with attributes testing of large lots of items submitted for testing or with writing specifications for such tests.

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TABLE OF CONTENTS

| Section | | Page |
|---------|--------------------------|------|
| I | Introduction | 1 |
| II | Assumptions and Formulas | 2 |
| III | Explanation of Graphs | 3 |
| | APPENDIXES | 5 |

SECTION I

INTRODUCTION

This technical report presents operating characteristic (OC) curves that give the probability, P , of a random sample from a binomial population being accepted versus the true reliability, R , of the lot, for sample size and acceptance number of defectives held fast. The graphs are for the lot tolerable percent defective (LTPD) = $p_0 = .01(.01).15$. The confidence levels, C , used are .5, .6, .7, .8, .9, .925, .950, .975, and .990. The sample defectives acceptance numbers, D , used are $D = 0(1)5, 10$, and 15.

The graphs should find many uses among the statisticians, engineers, and quality assurance workers who are concerned with attributes testing of large lots of items submitted for inspection, or with writing specifications for such tests.

SECTION II

ASSUMPTIONS AND FORMULAS

It is assumed that large lots are to be submitted for attribute acceptance inspection and that sample sizes, N , are small in comparison to lot sizes. With this assumption, the binomial distribution governs the probability of a random sample passing the inspection test with acceptance of the lot. If this assumption were not justified, the hypergeometric distribution would apply, rather than the binomial distribution.

Sample size, N , was computed as a function of p_0 (the lot tolerable percent defection, LTPD), the defection acceptance number, D , and the confidence level, C . The number, N , was selected as the least positive integer satisfying the inequality :

$$\sum_{x=0}^D \binom{N}{x} p_0^x (1 - p_0)^{N-x} \leq 1 - C$$

With the sample size thus obtained, the probability, P , that a random sample of size N would be accepted was computed as a function of true reliability, R :

$$P = \sum_{x=0}^D \binom{N}{x} (1-R)^x R^{N-x}$$

The values of P versus R were tabulated and graphed with N , C , and D as parameters. It will be noted that all the graphs on one figure pass through or very near the point $P = 1 - C$; $R = 1 - p_0$. The need to use integral values of sample size, N , in the relations for P is the reason the curves do not always pass exactly through these points.

SECTION III

EXPLANATION OF GRAPHS

Appendixes I through XV present the graphs for curves for lot tolerable percent defective (p_0) = 0.01 through $p_0 = 0.15$. Each graph contains eight curves, one each for $D = 0, 1, 2, 3, 4, 5, 10$, and 15 . In the top portion of the graphs, the value of the defectives acceptance number, D , increases from left to right. That is, the top portion of the curve farthest to the left has $D = 0$, while the curve farthest to the right has $D = 15$. The order is reversed for the portion of the curves at the bottom of the graphs or pages. The point on the graphs where the curves intersect is $(R, P)_0 = (1 - p_0, 1 - C)$. As an example of the use of these curves, suppose the requirement were made that a product tested should have 90% reliability with 80% confidence level. The OC curves, with sample sizes and acceptance numbers for this case may be found on page 99. This graph has $p_0 = 1 - R = 0.1 - 0.900 = 0.100$, and $C = 0.80$. The curve $D = 0$ requires sample size $N = 16$; while $D = 1$ requires sample size $N = 29$, etc. The curves for larger values of D approach more closely to an ideal shape for an OC curve, but carry the penalty of larger sample requirements.

1. SYMBOLS AND ABBREVIATIONS

The following symbols and abbreviations are used on the graphs:

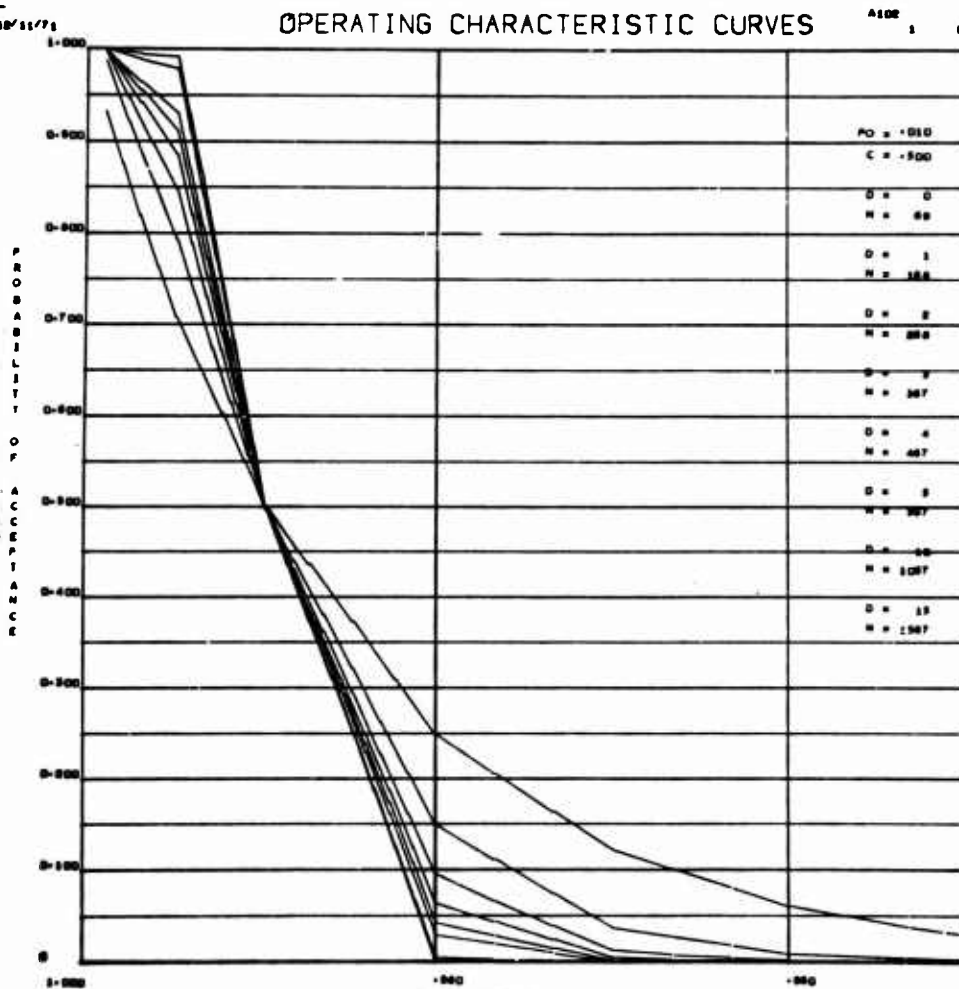
| | |
|-------|--|
| C | Confidence Level |
| D | Acceptance Number |
| N | Sample Size |
| P | Probability of a Sample Being Accepted |
| p_0 | Fraction Defective, Lot Tolerable Percent Defective (LTPD) |
| R | True Reliability |

APPENDIX I

OPERATING CHARACTERISTIC
CURVES ($p_0 = .010$)

OPERATING CHARACTERISTIC CURVES

A102

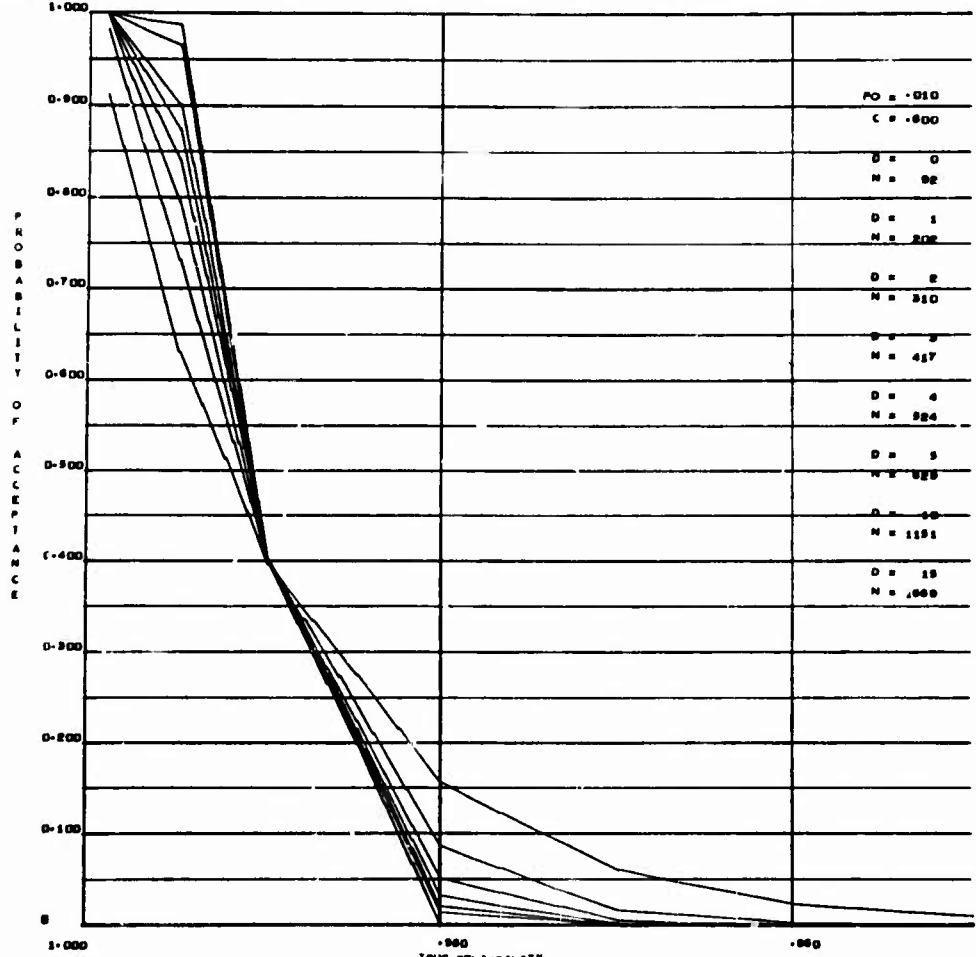


TRUE RELIABILITY
PLOT PREPARED BY T&A, ADTC

12/11/73

OPERATING CHARACTERISTIC CURVES

A102 2 0



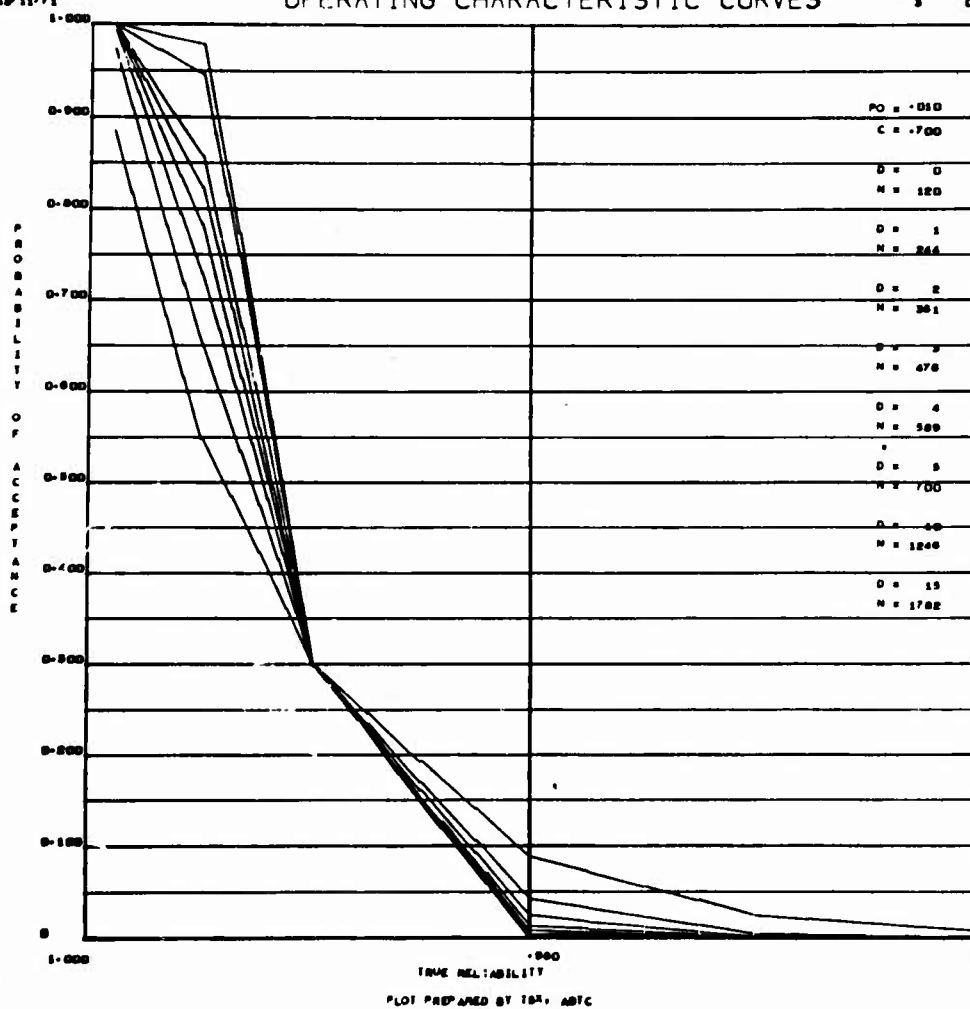
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OPERATING CHARACTERISTIC CURVES

4102

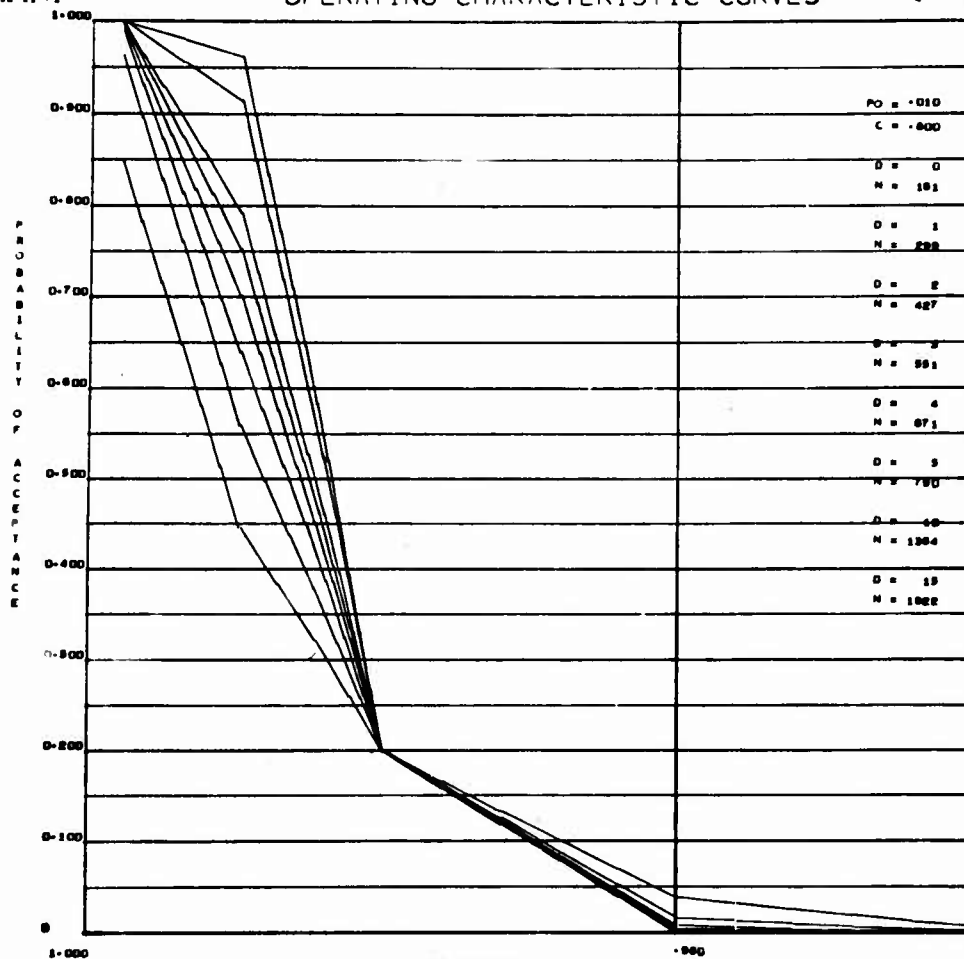
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12/11/71

OPERATING CHARACTERISTIC CURVES

A102 4 0

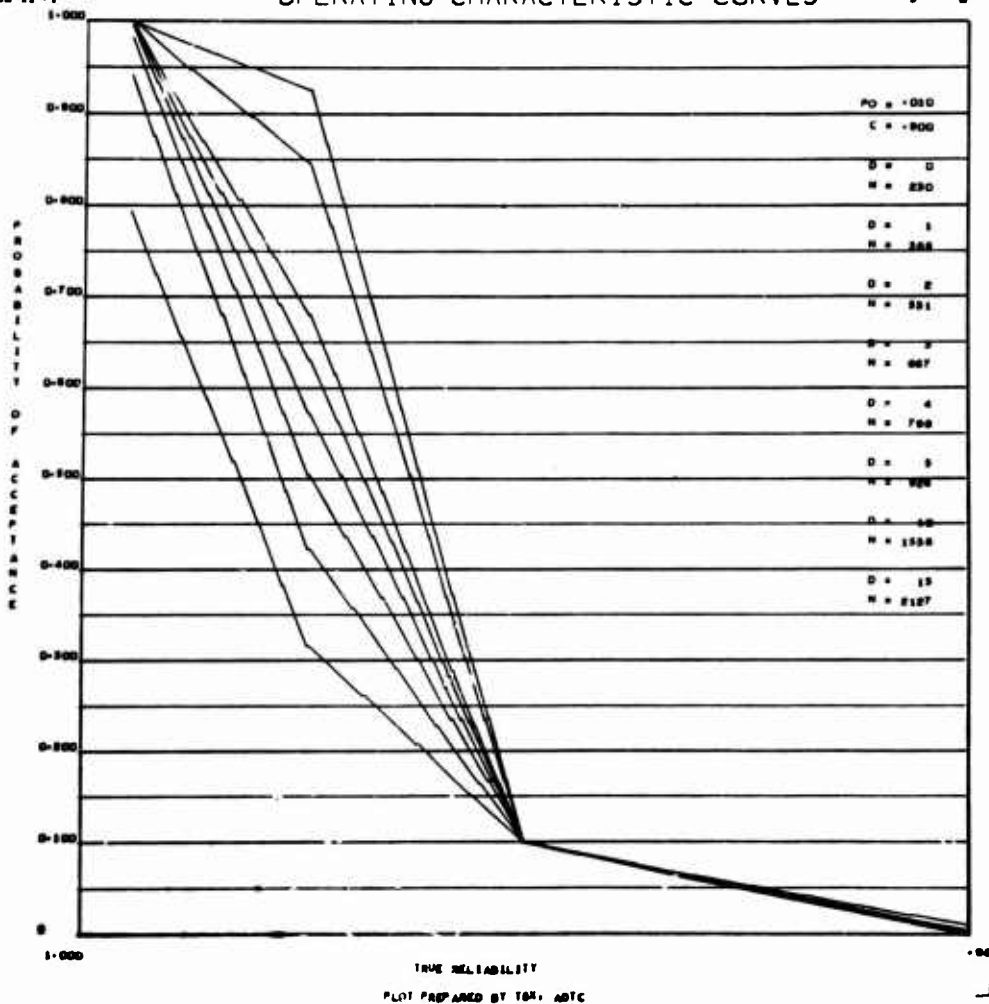


TRUE RELIABILITY
PLOT PREPARED BY T&A ADTC

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OPERATING CHARACTERISTIC CURVES

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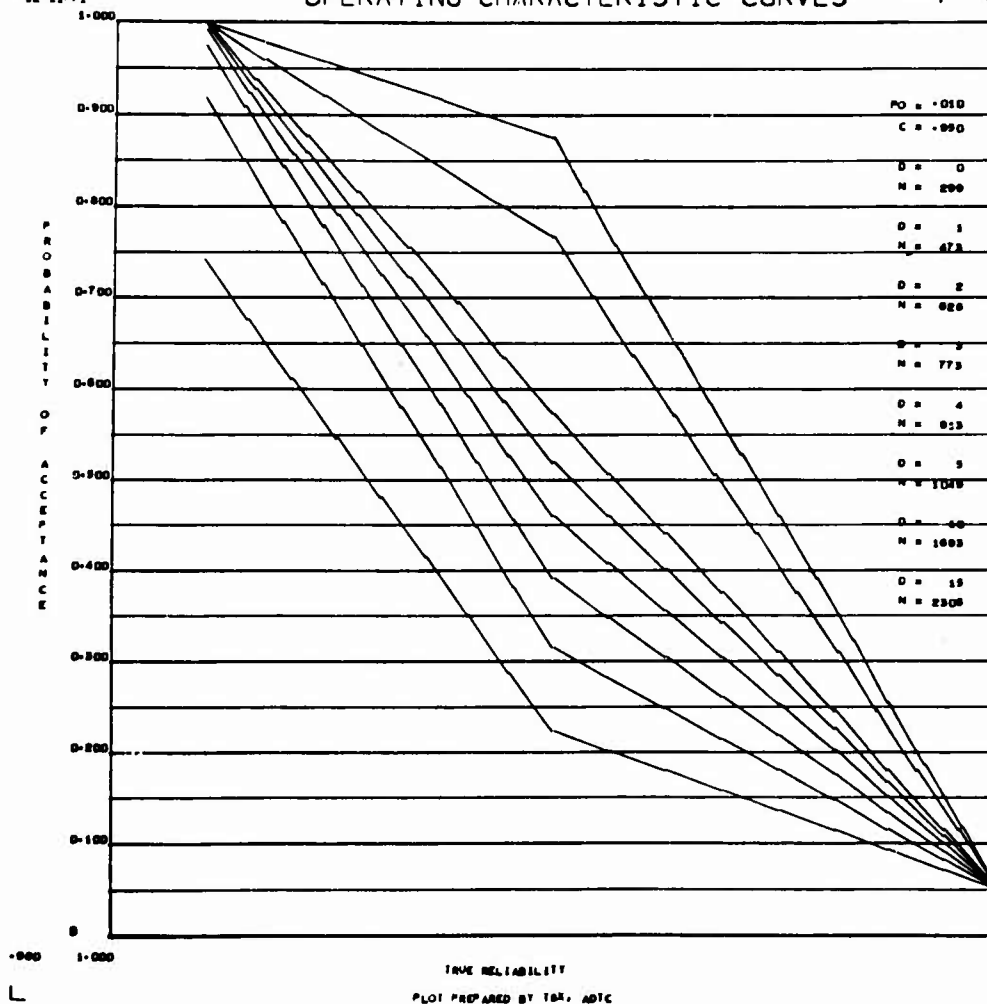
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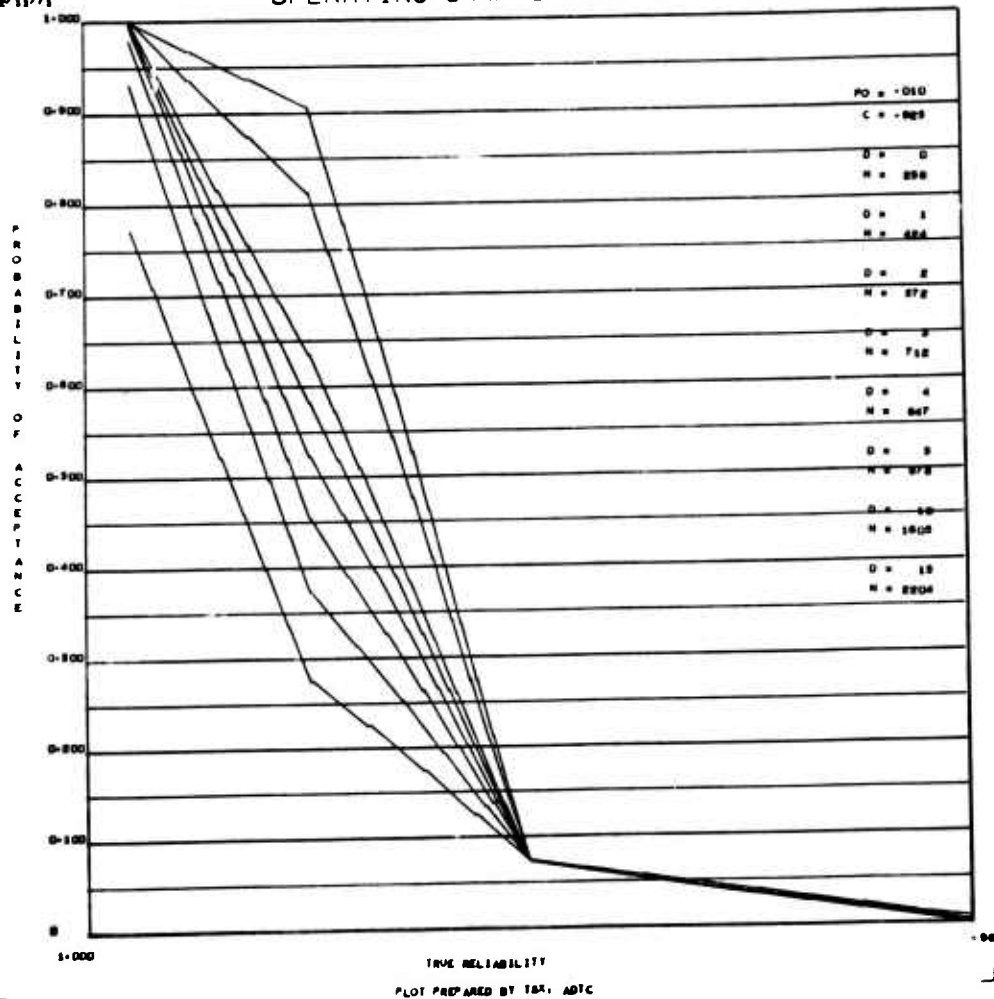
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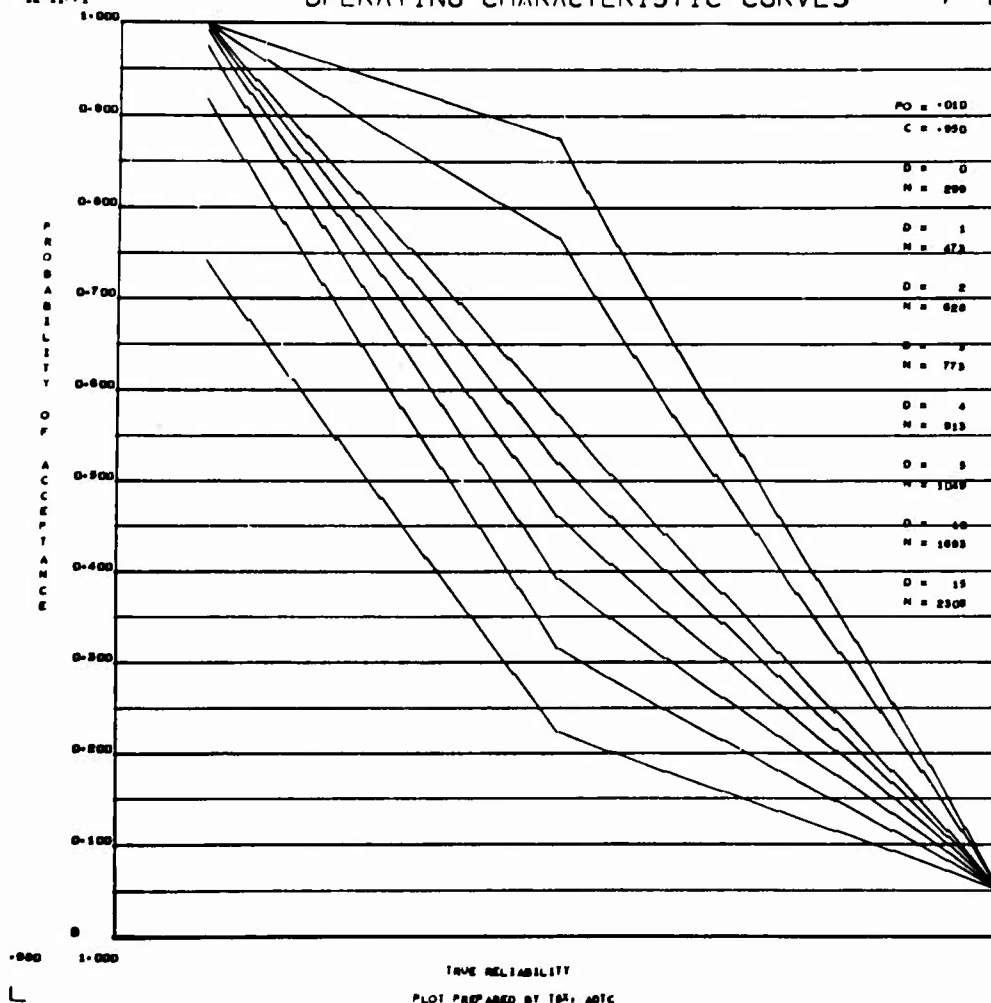
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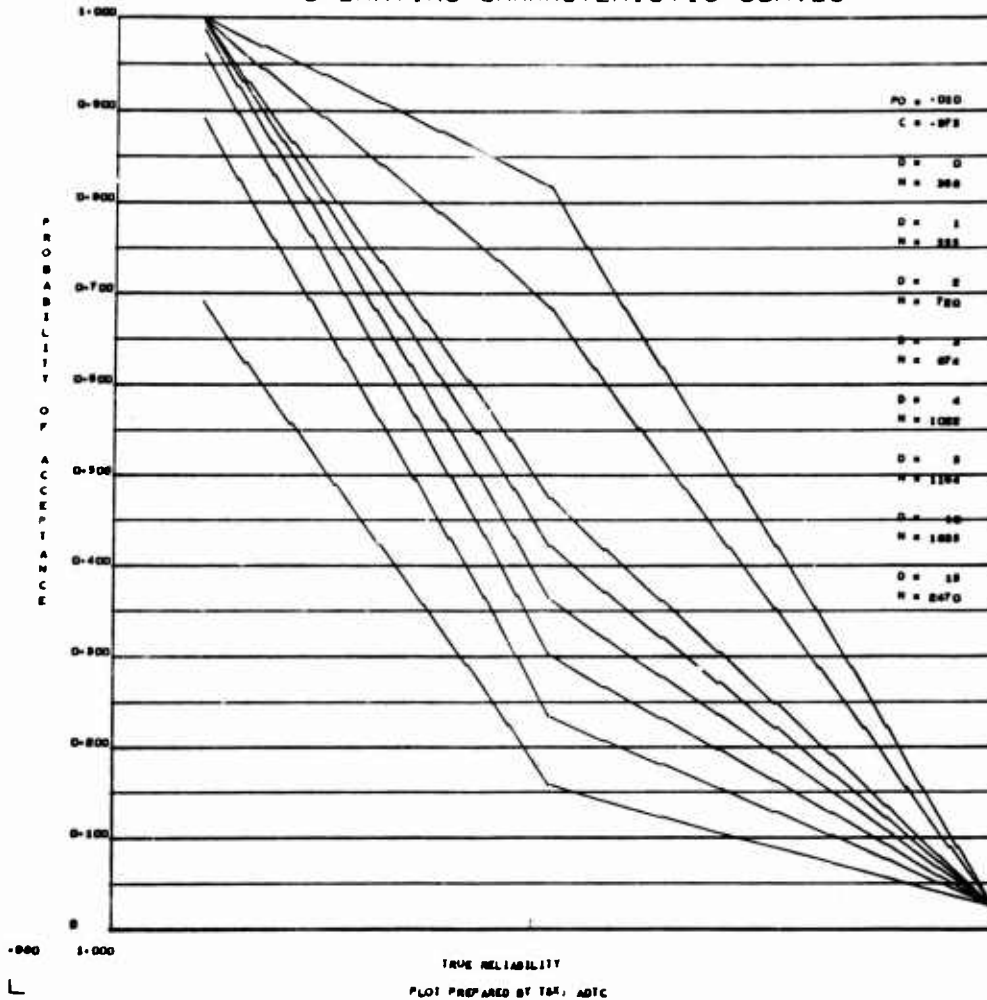
A108, 07



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OPERATING CHARACTERISTIC CURVES

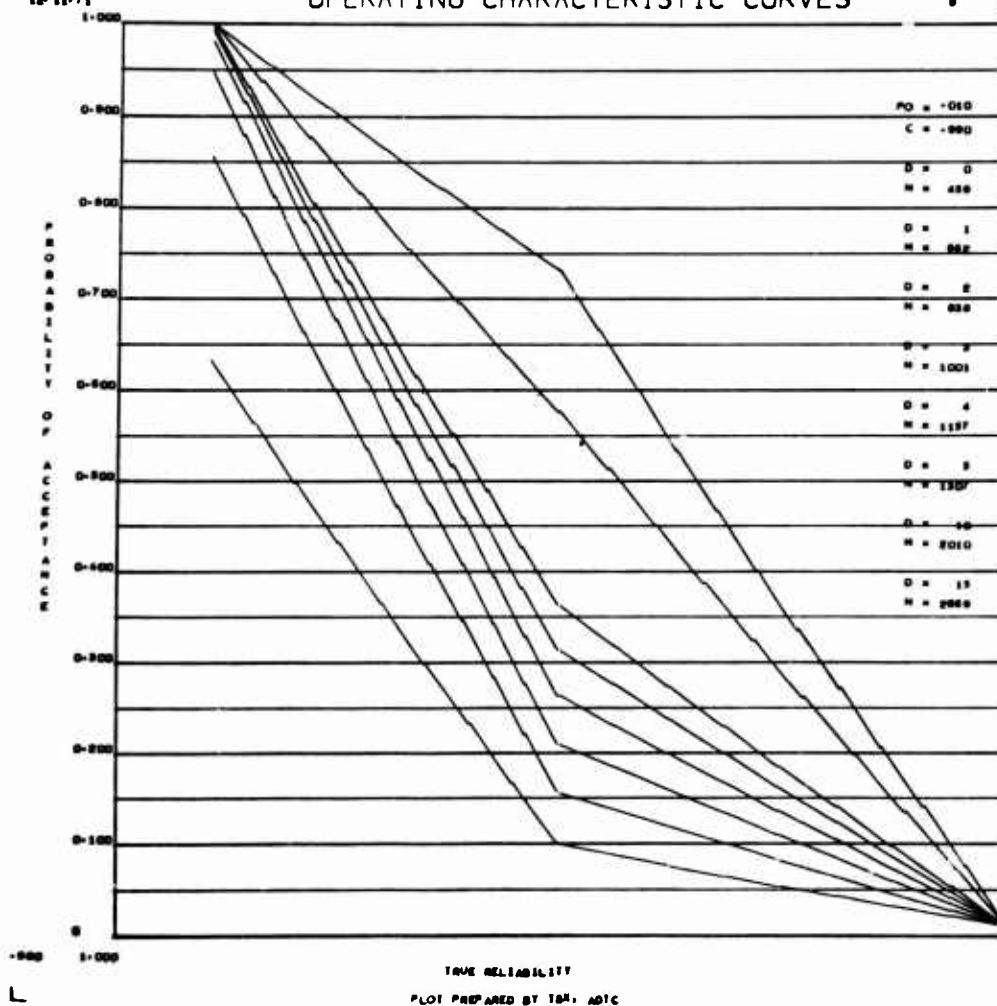
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OPERATING CHARACTERISTIC CURVES

A102 . 07

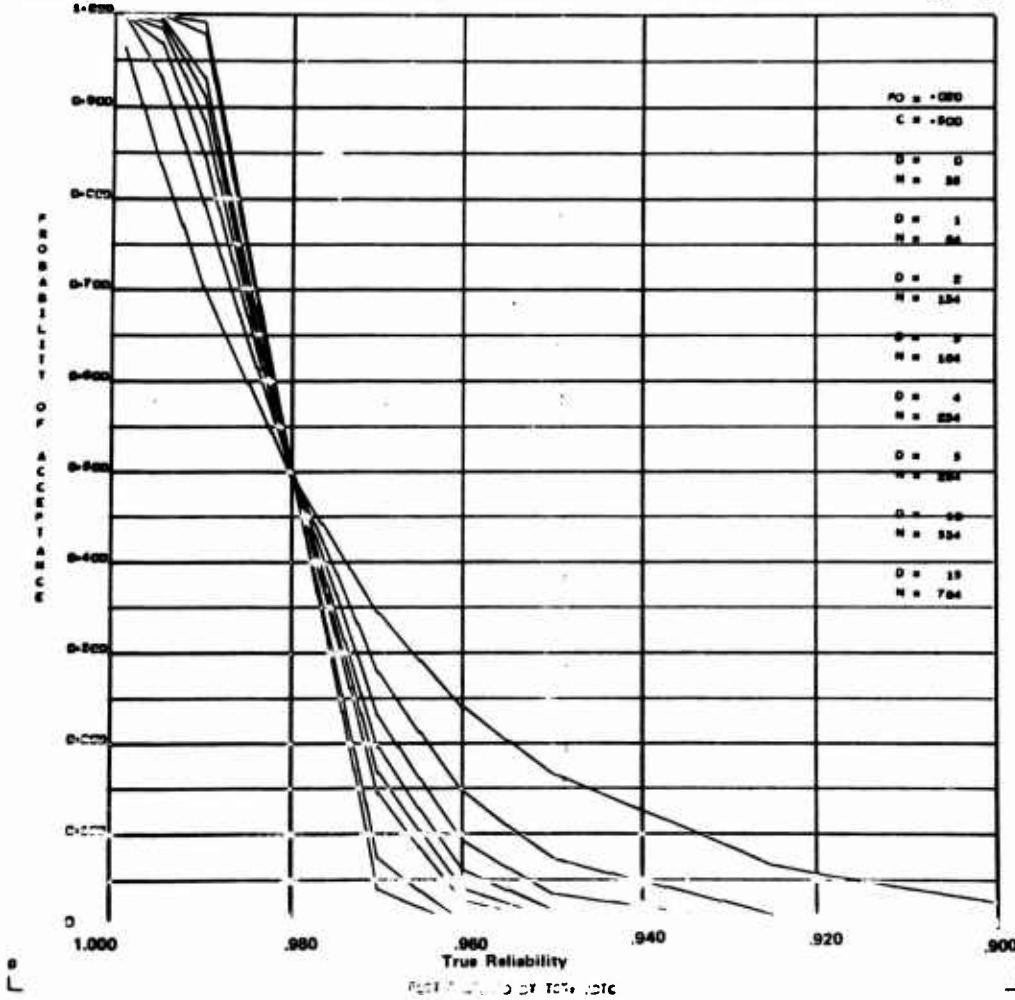


APPENDIX II
OPERATING CHARACTERISTIC
CURVES ($p_0 = .020$)

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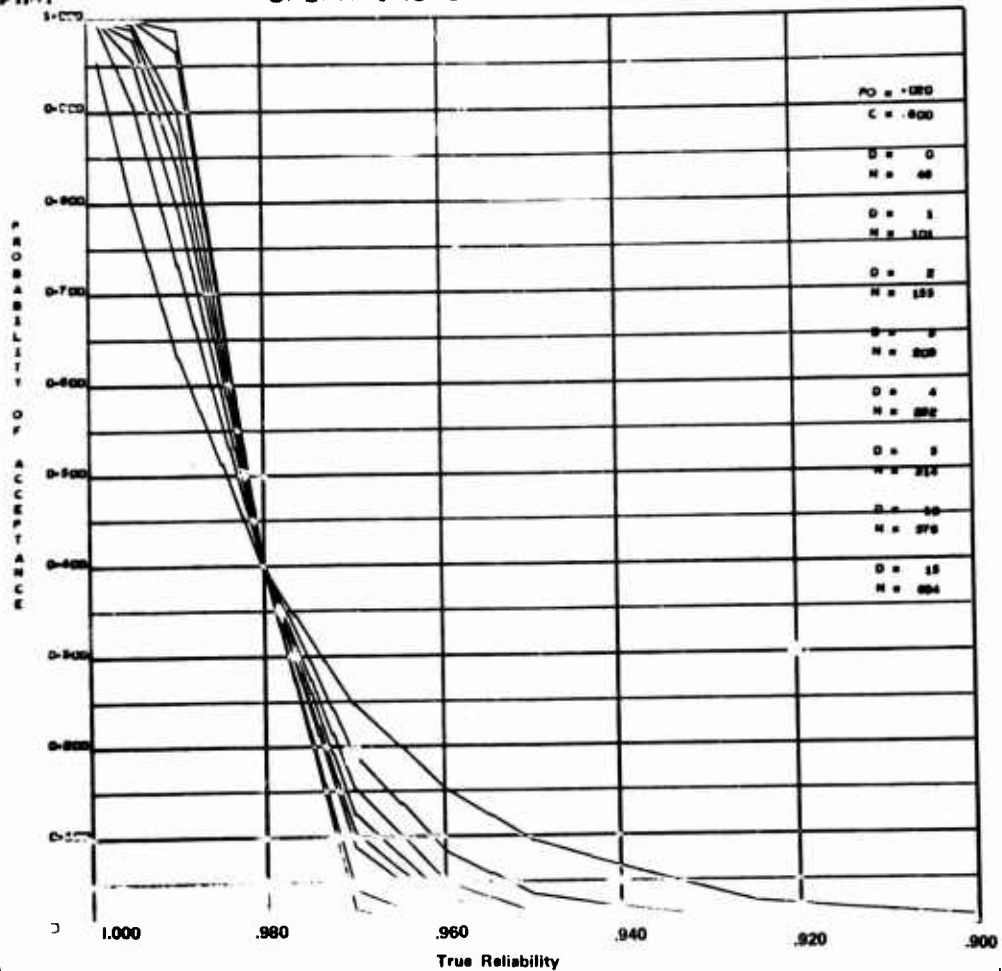
OPERATING CHARACTERISTIC CURVES

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OPERATING CHARACTERISTIC CURVES

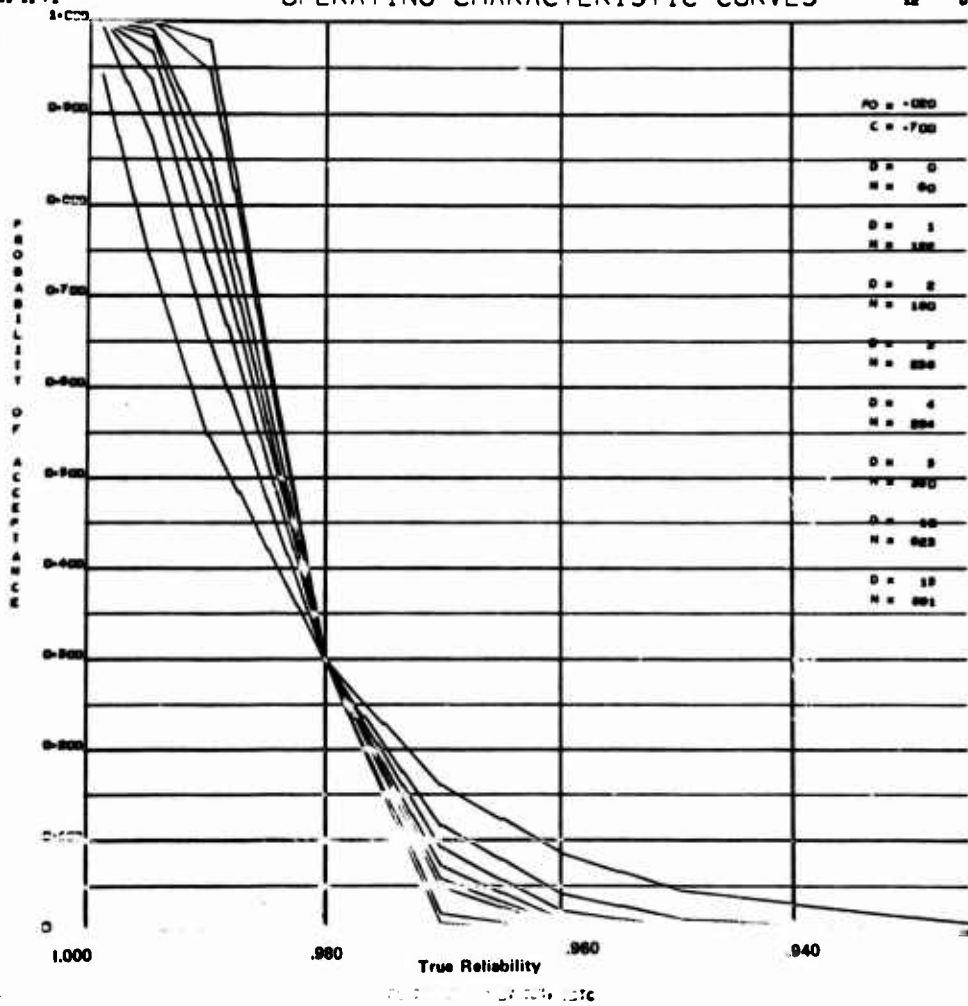
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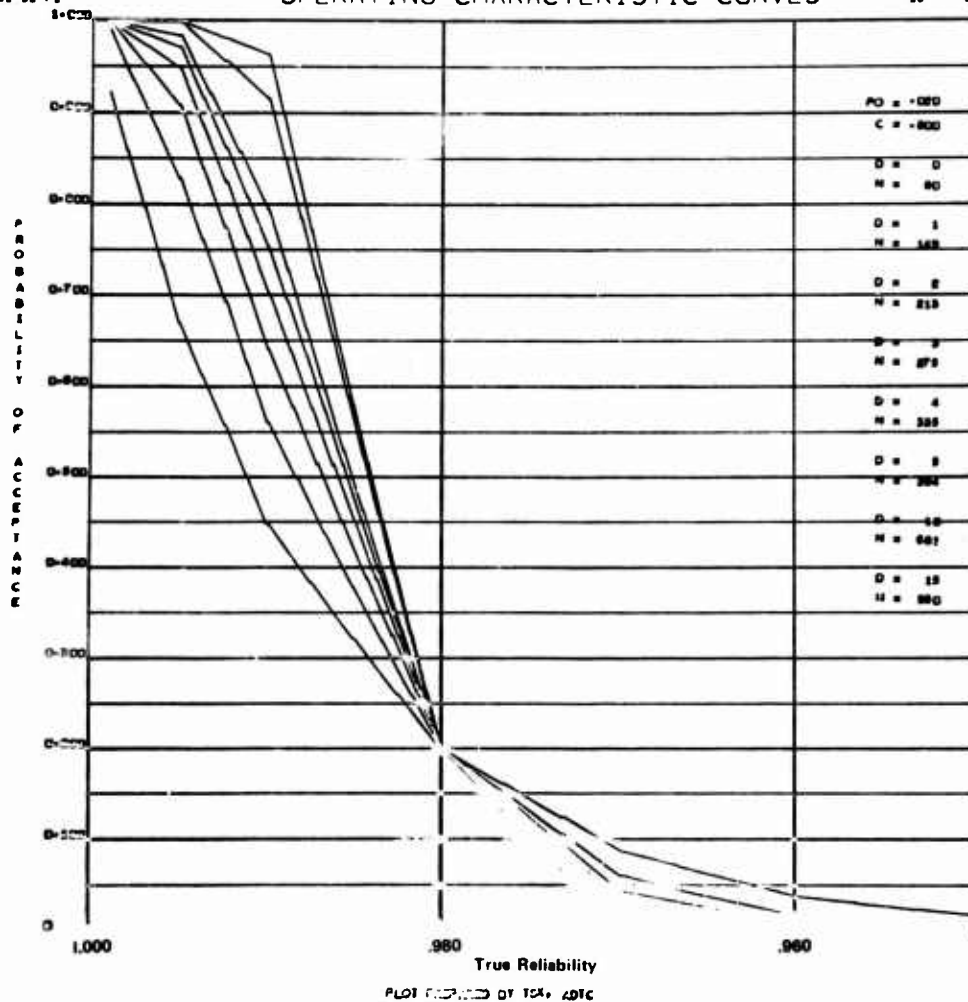
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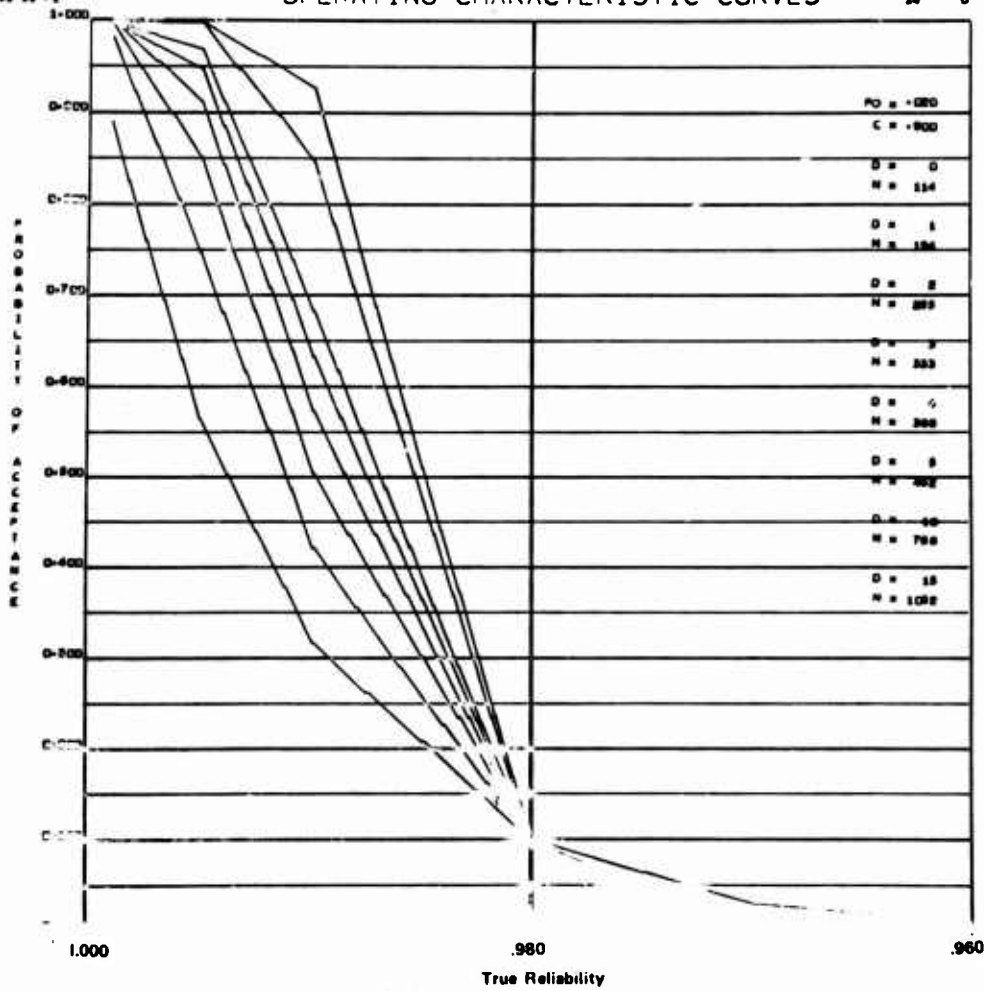
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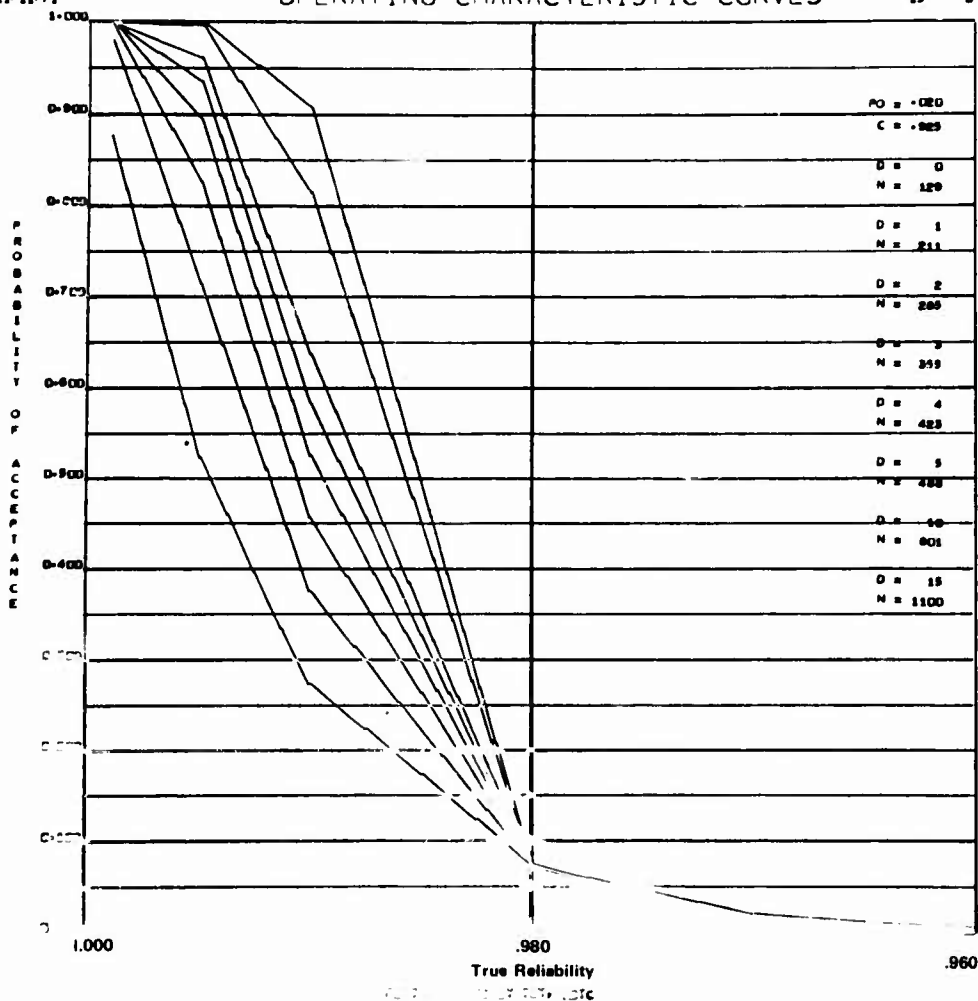
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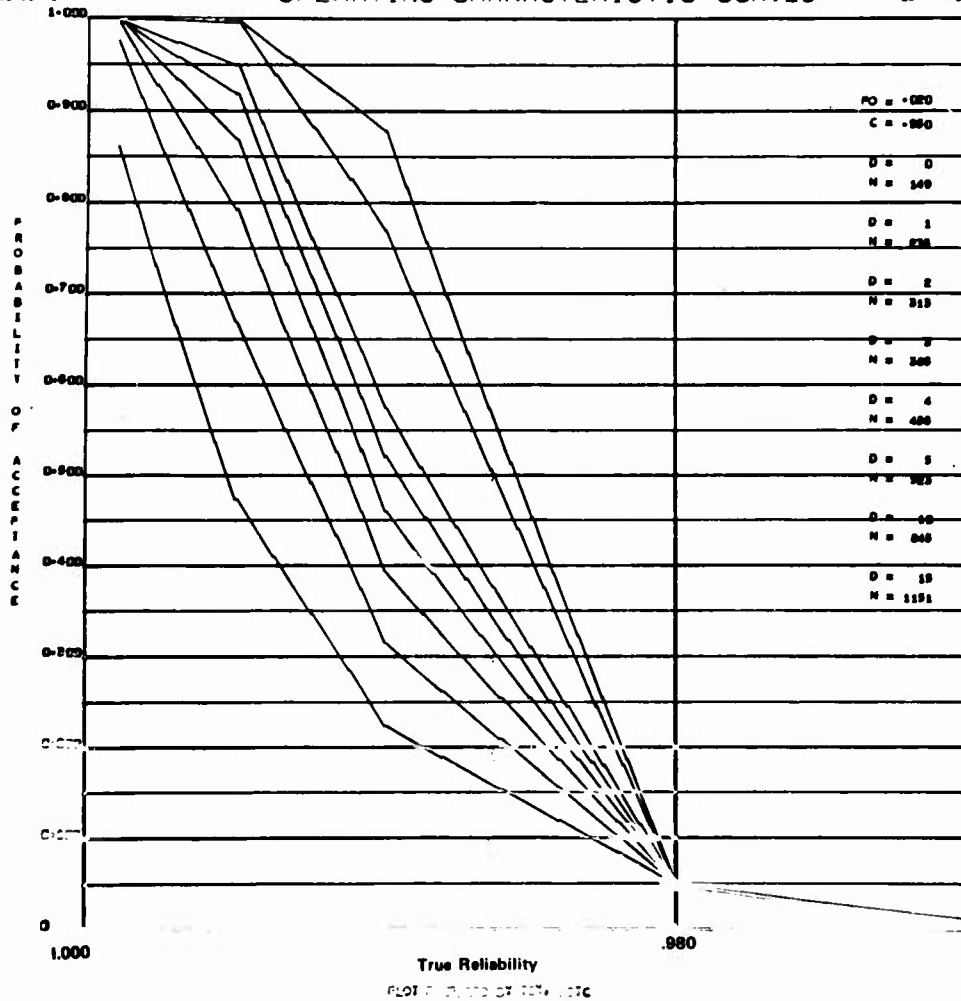
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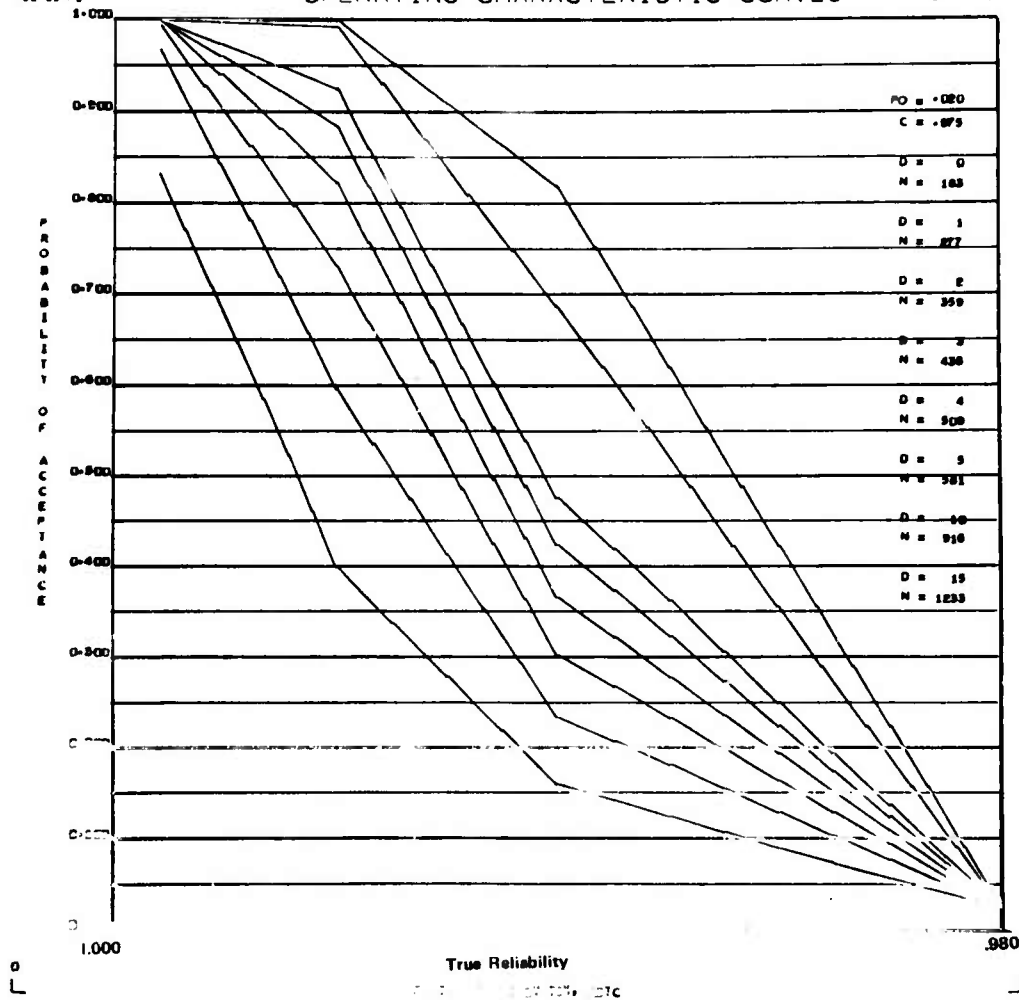
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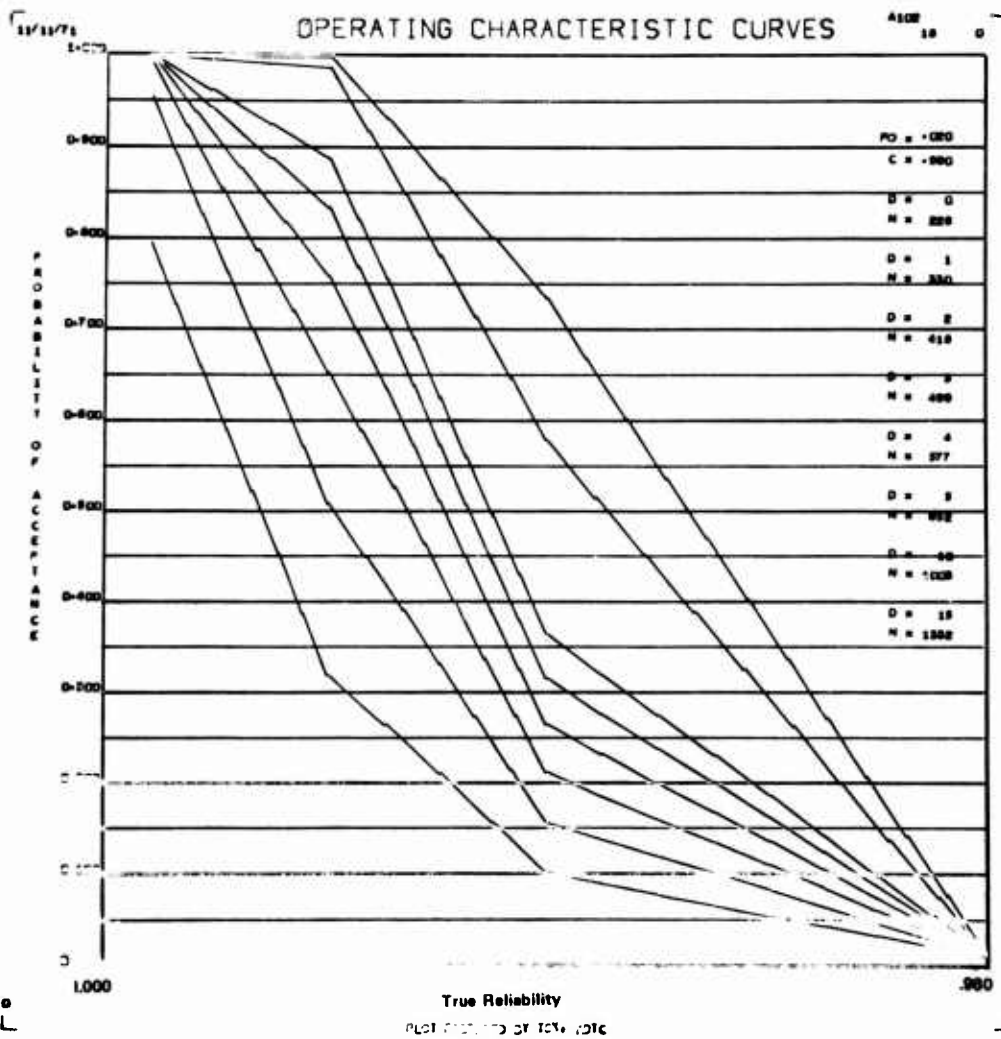


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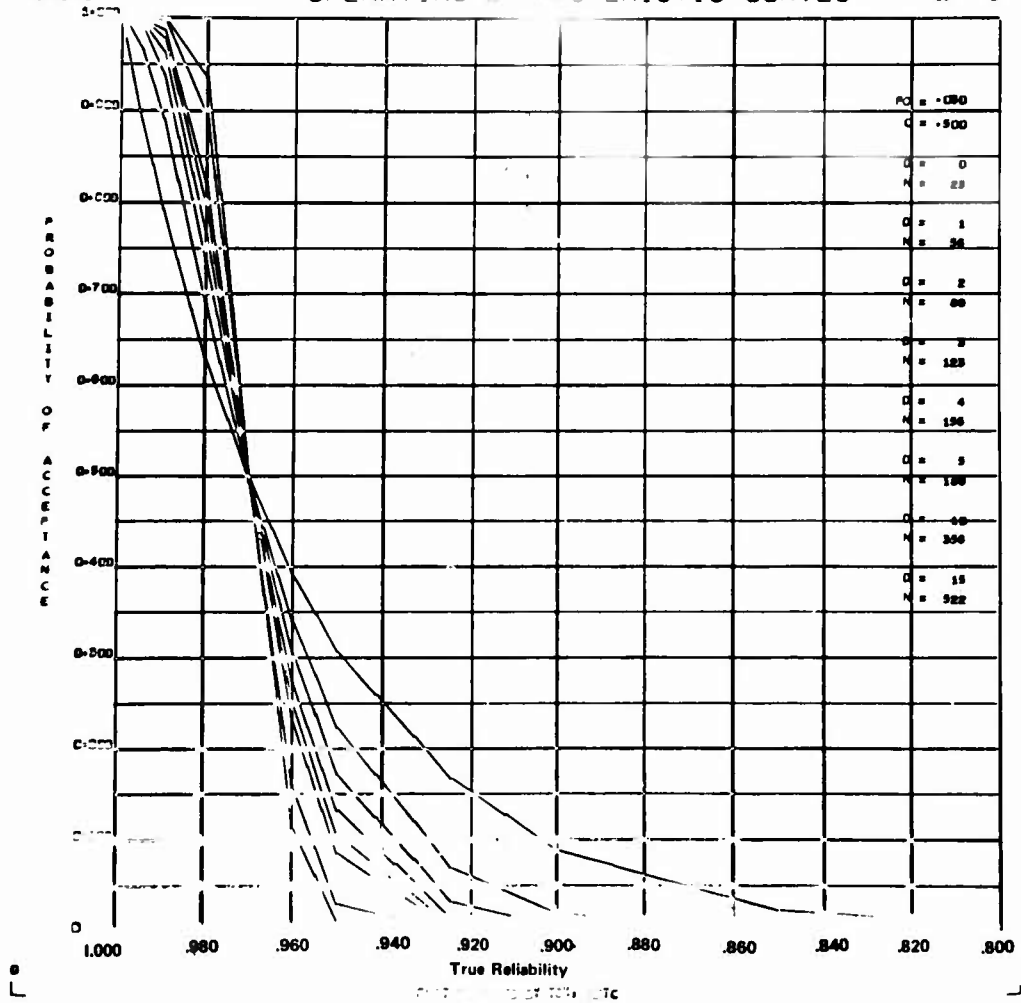
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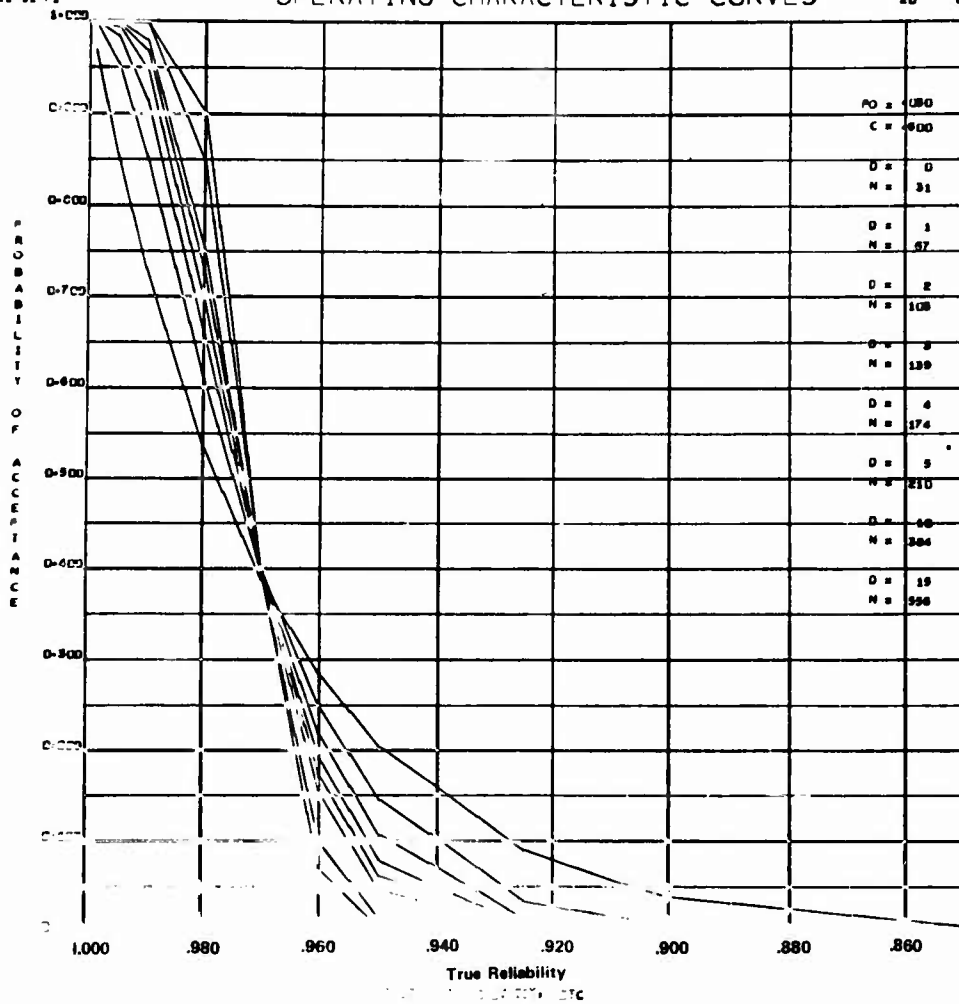
APPENDIX III
OPERATING CHARACTERISTIC
CURVES ($p_0 = .030$)

OPERATING CHARACTERISTIC CURVES



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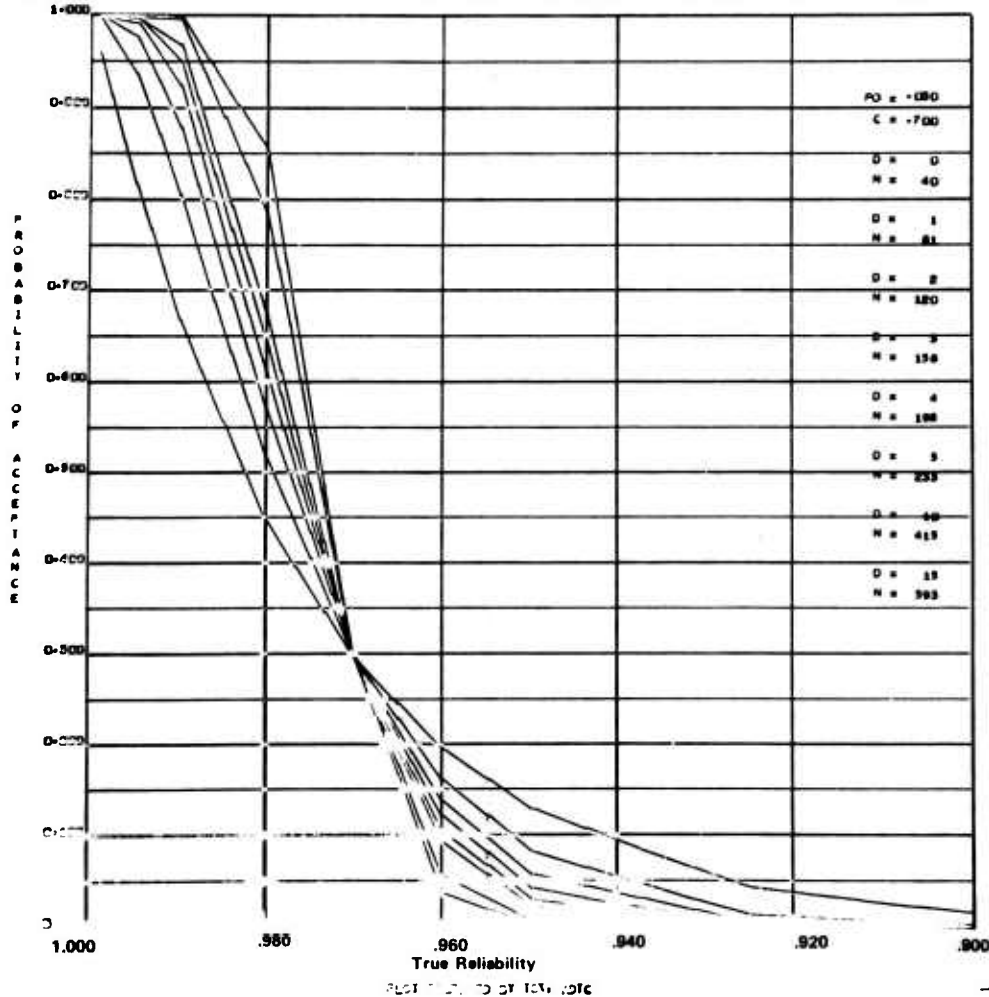
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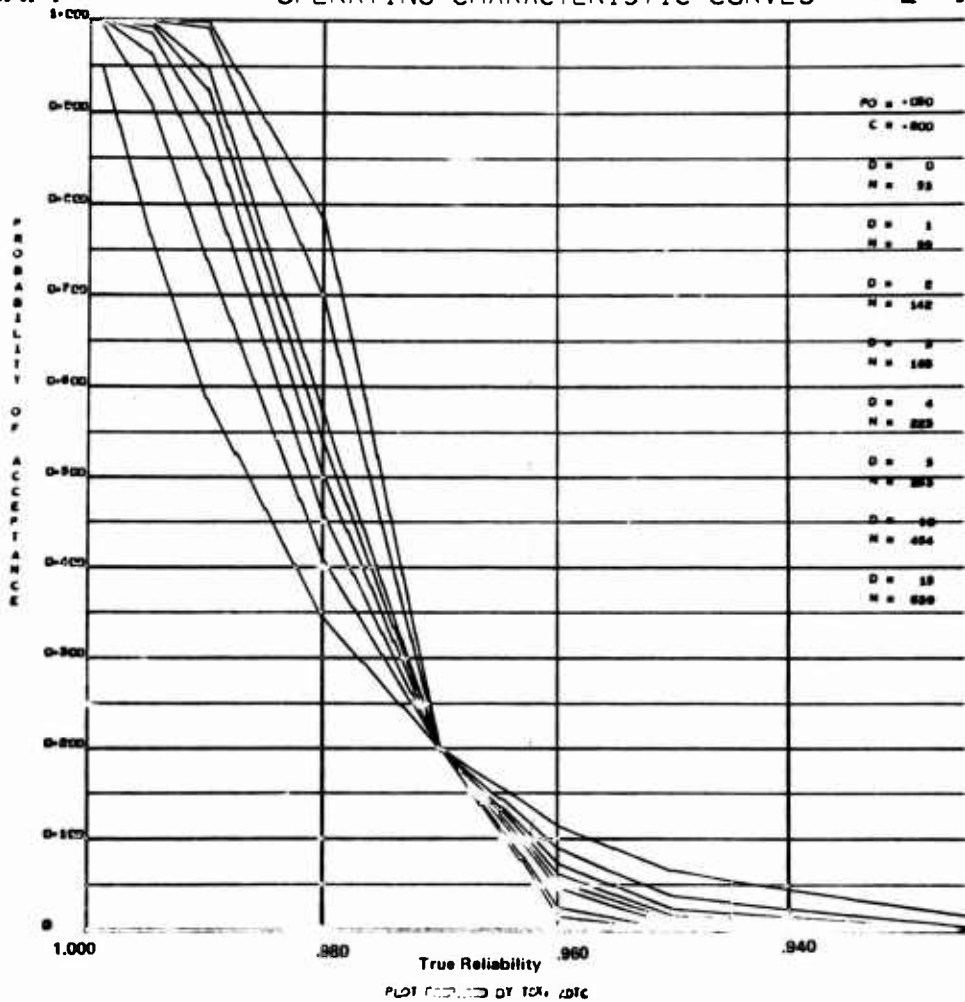
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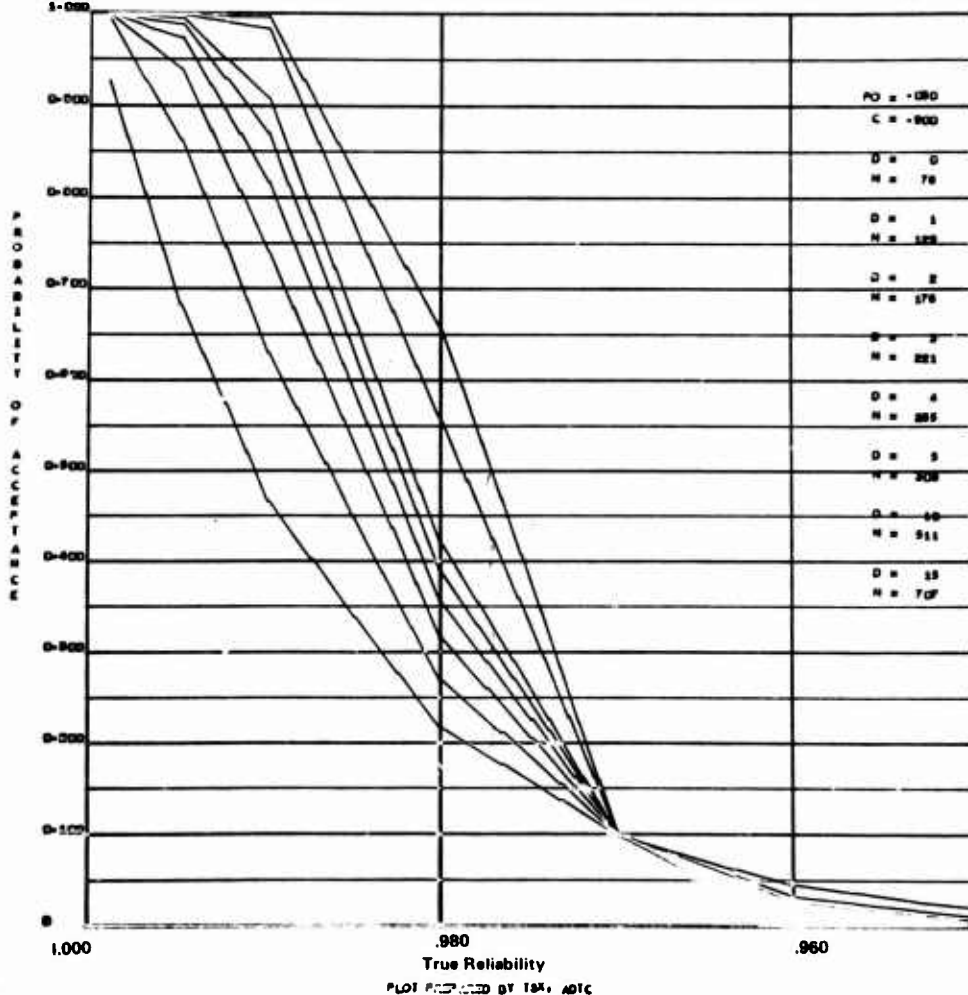
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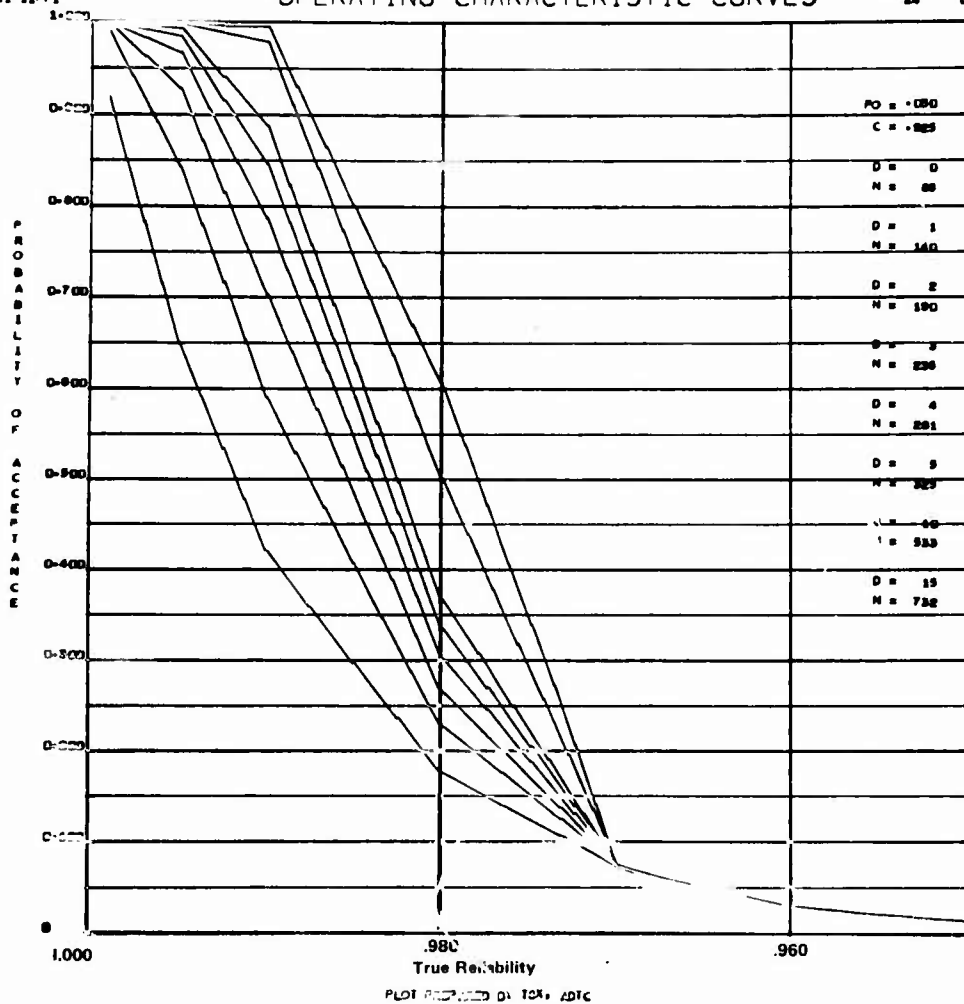
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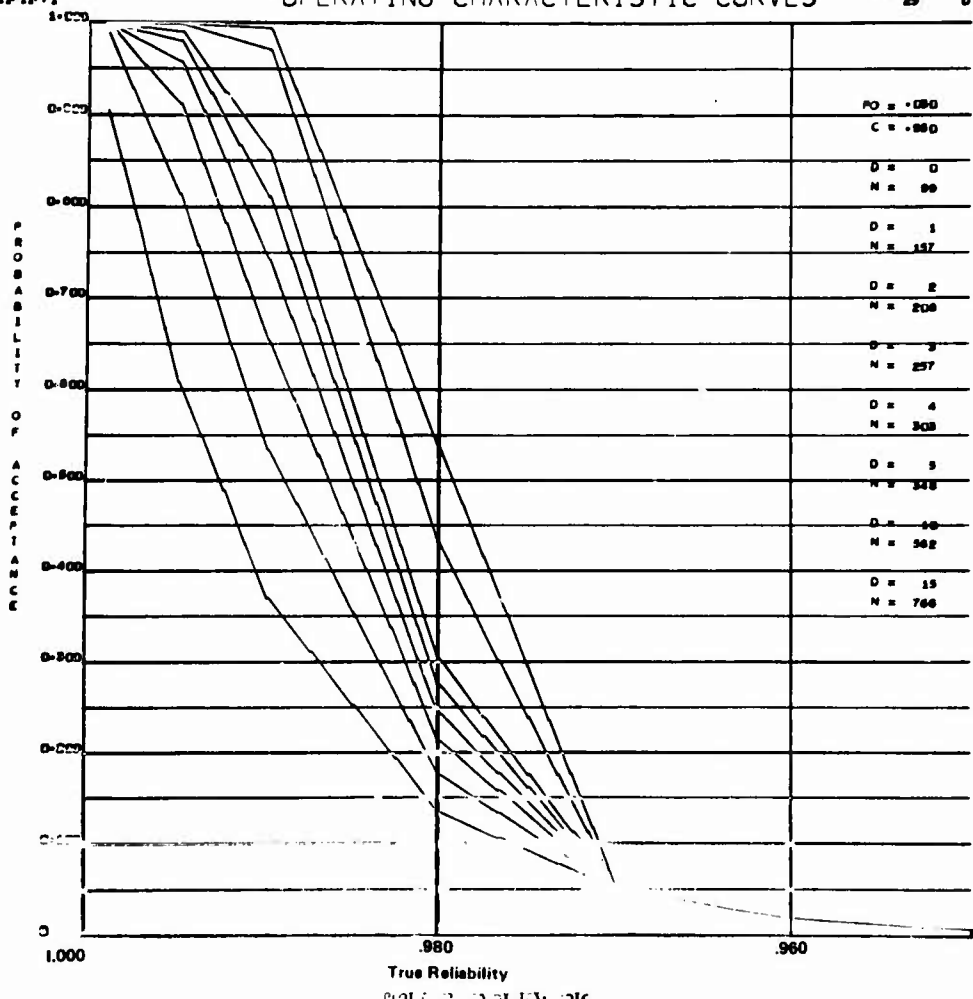
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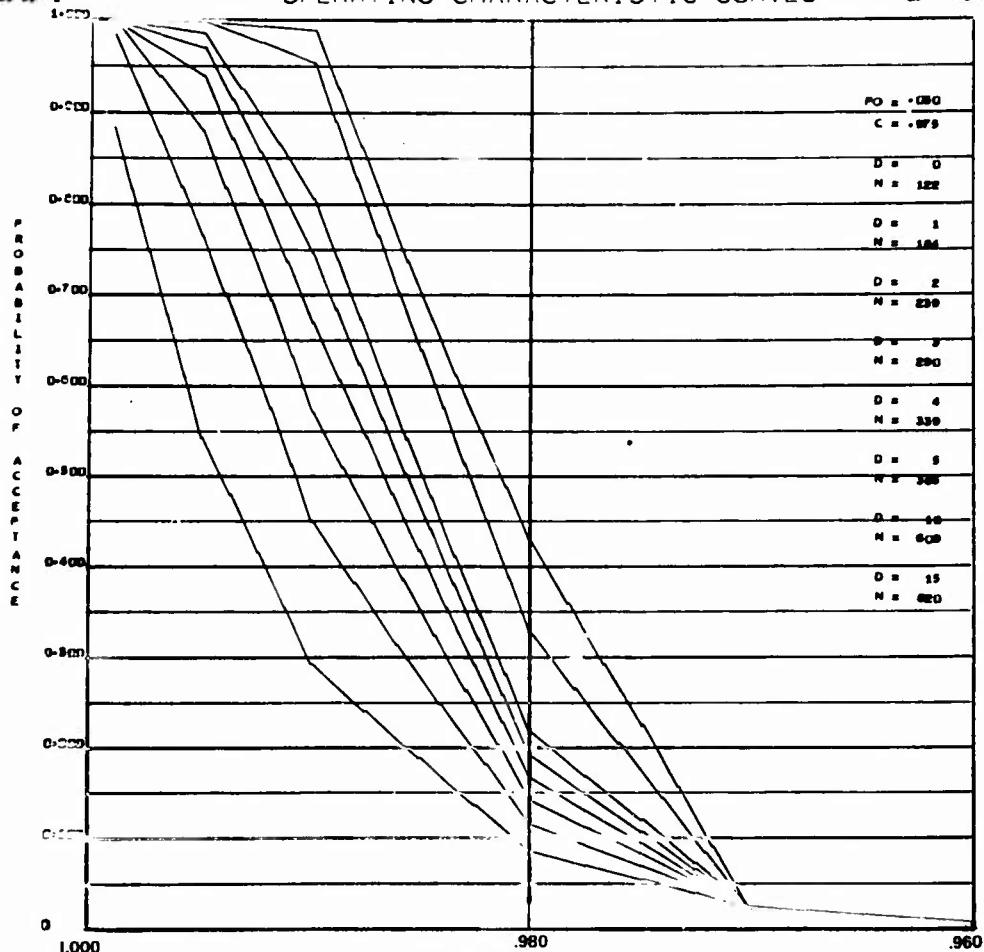


True Reliability
 PLOT OF P_a vs P_T (P_T = P₀)

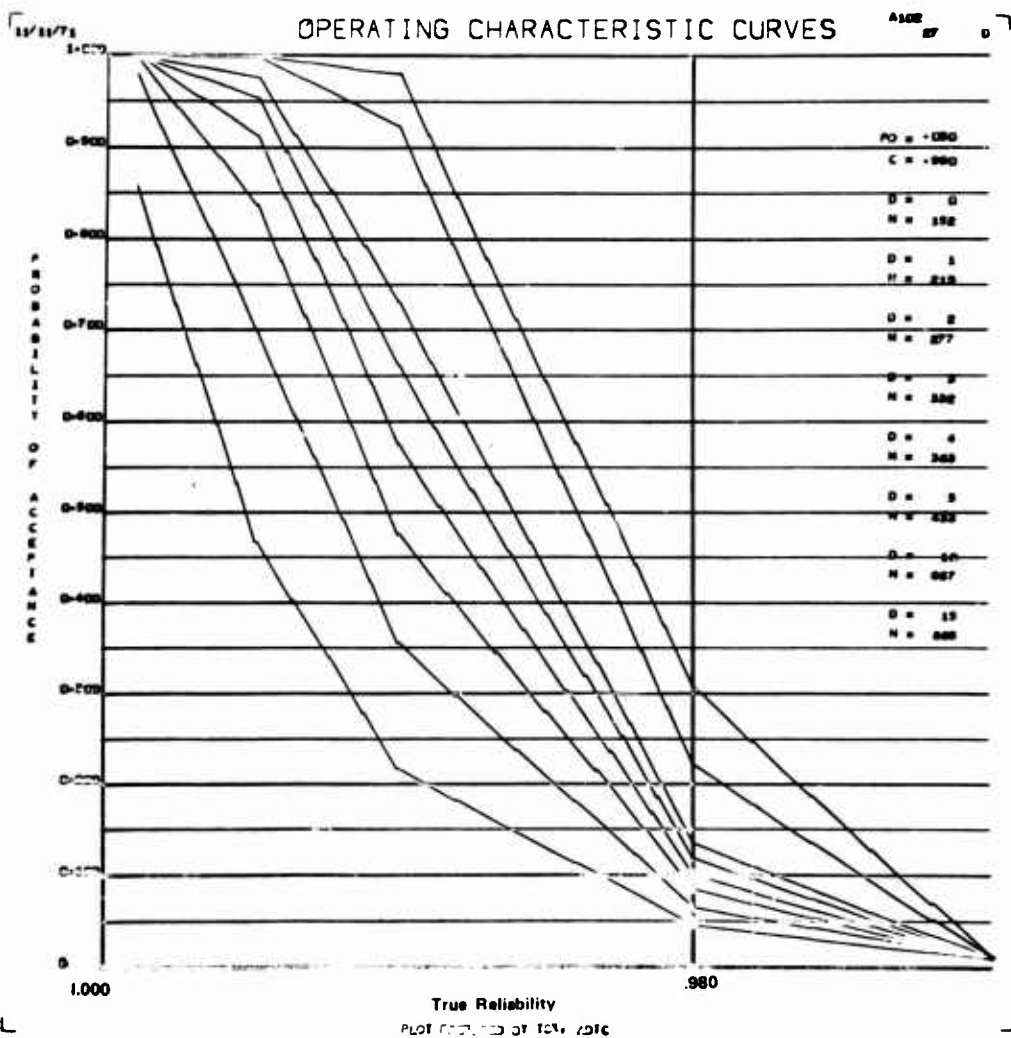
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OPERATING CHARACTERISTIC CURVES

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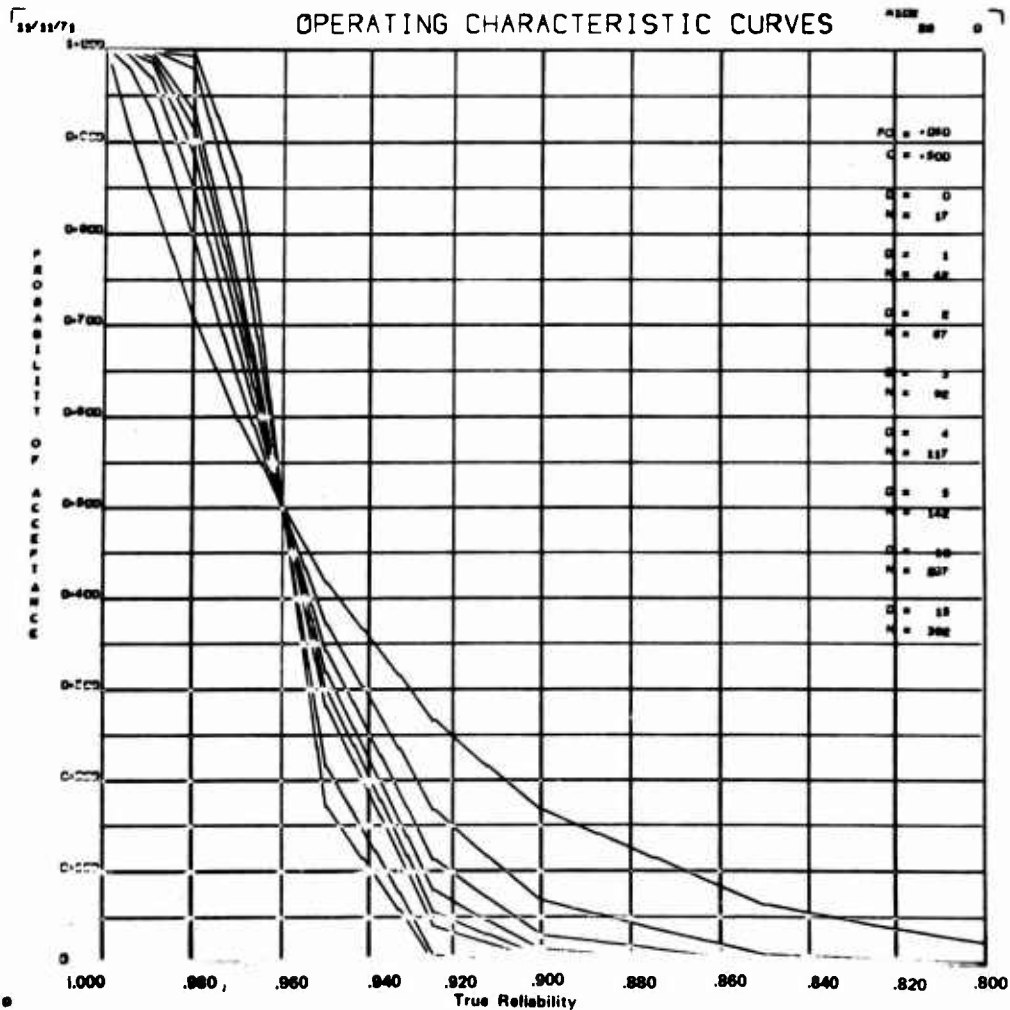


True Reliability
PLOT PREPARED BY 10X, LDT



APPENDIX IV
OPERATING CHARACTERISTIC
CURVES ($p_0 = .040$)

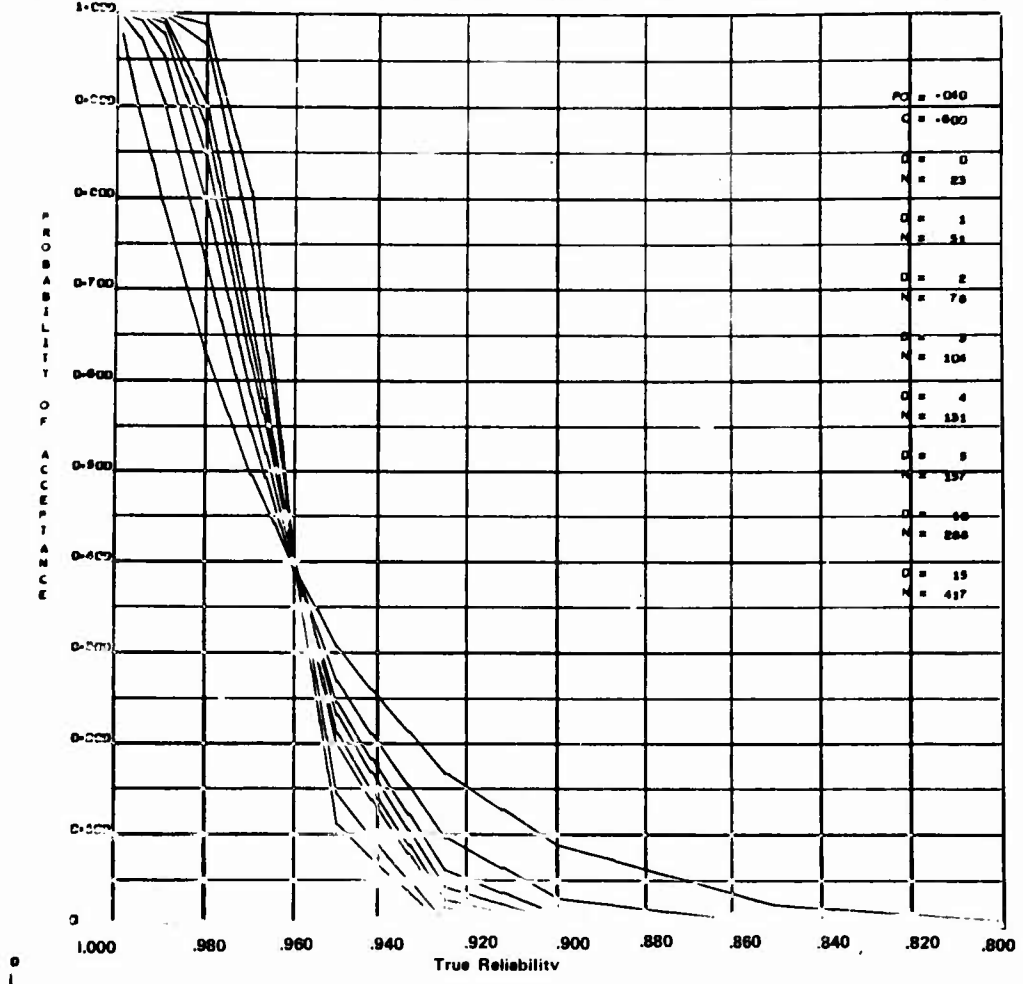
OPERATING CHARACTERISTIC CURVES



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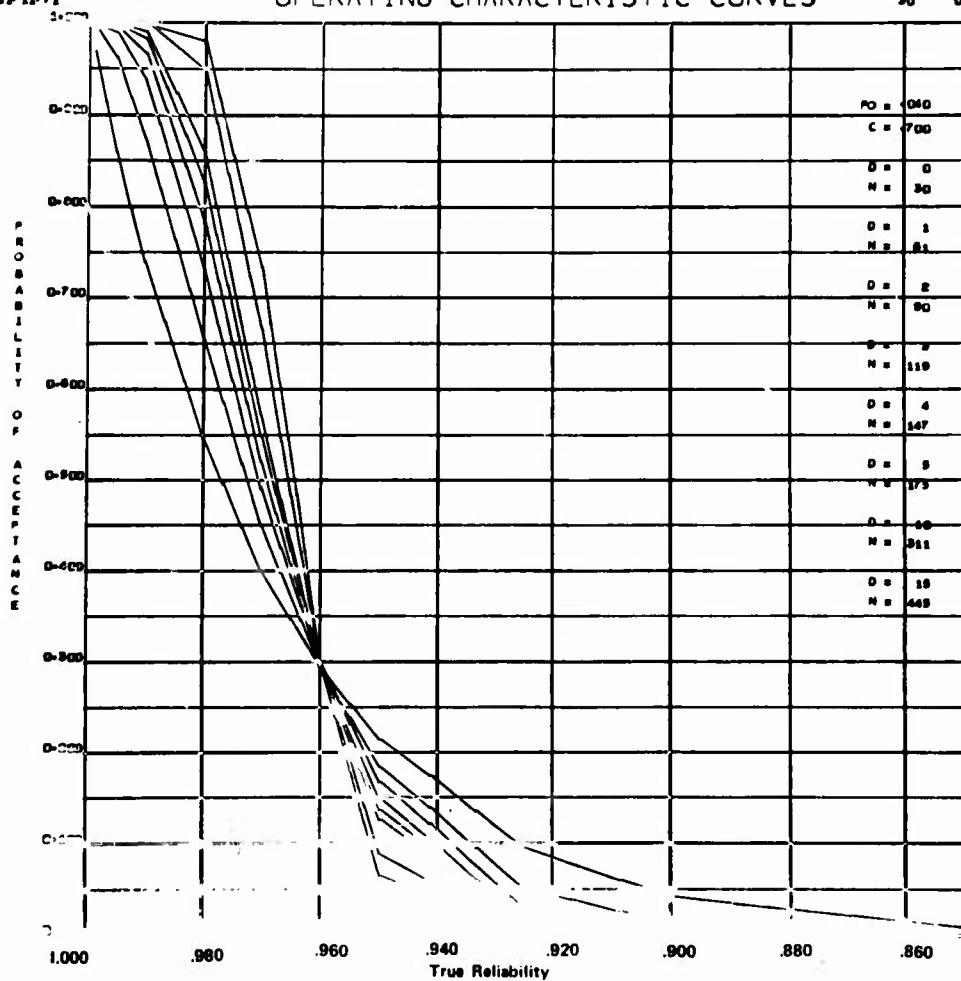
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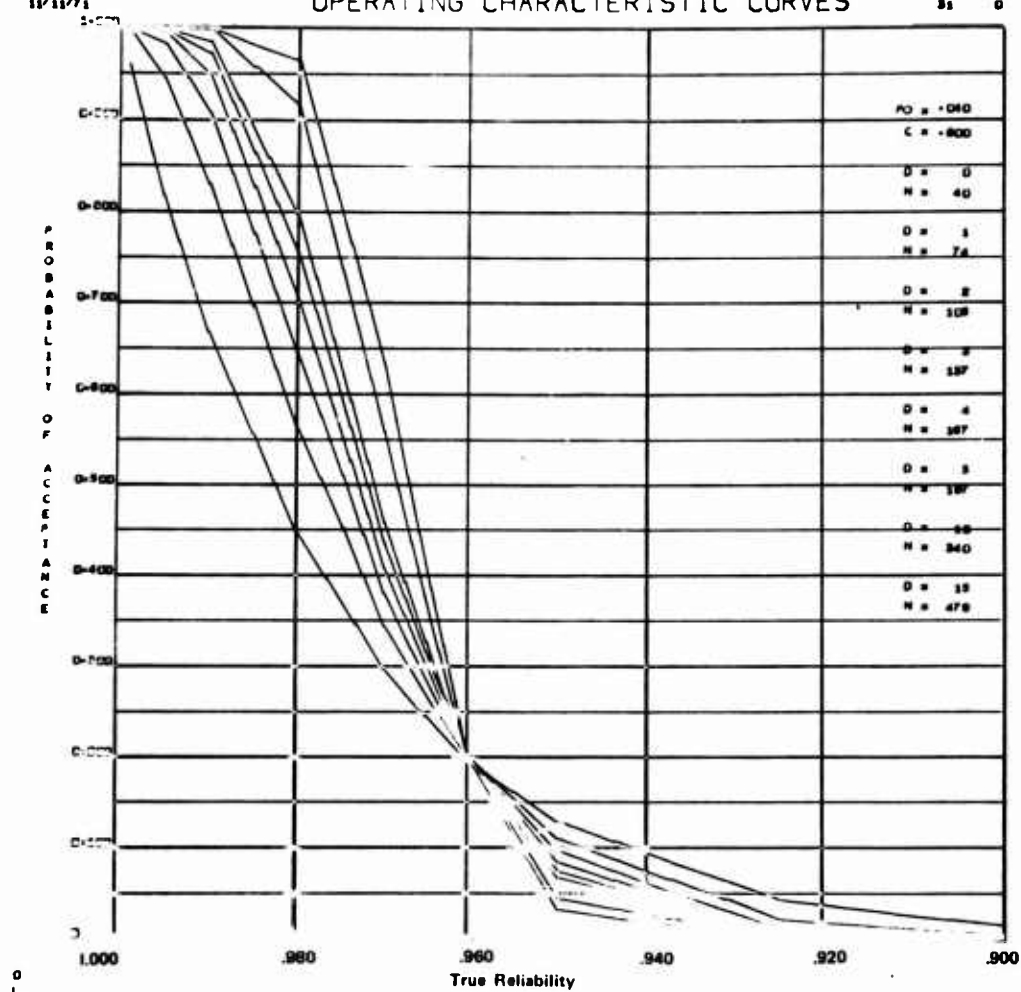
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OPERATING CHARACTERISTIC CURVES

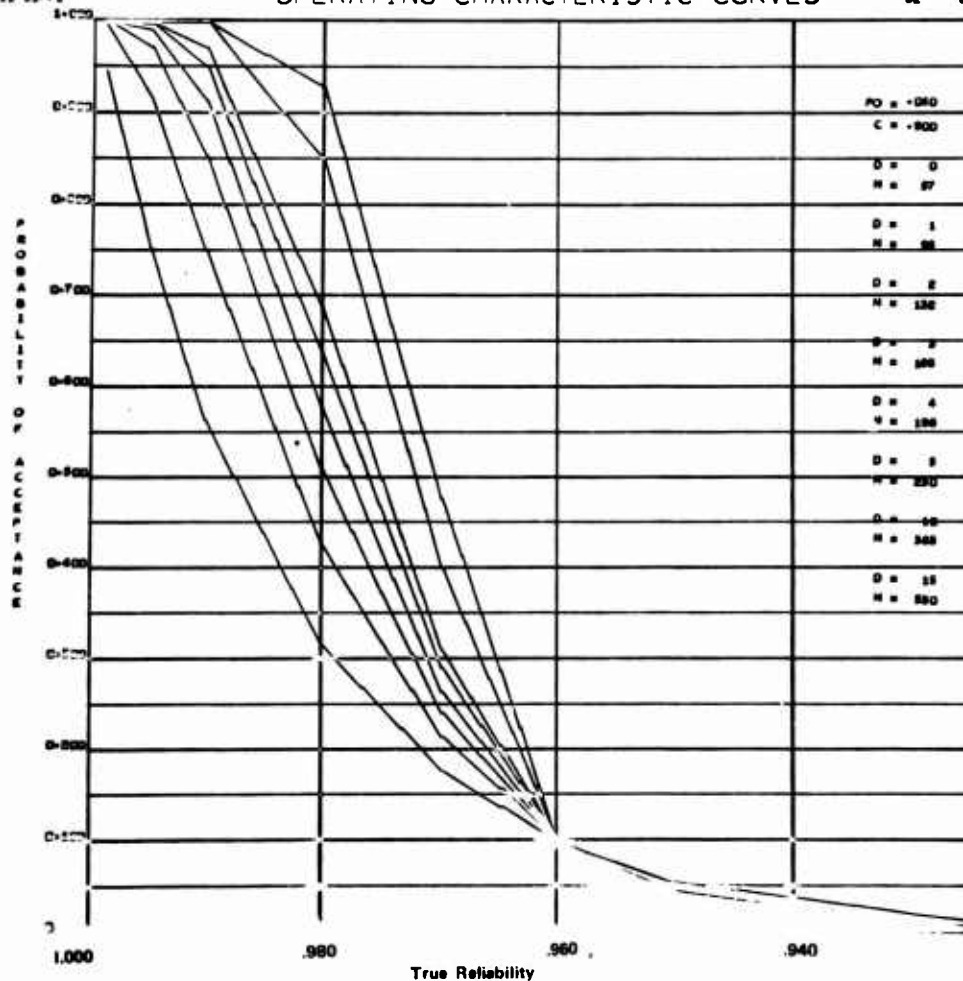
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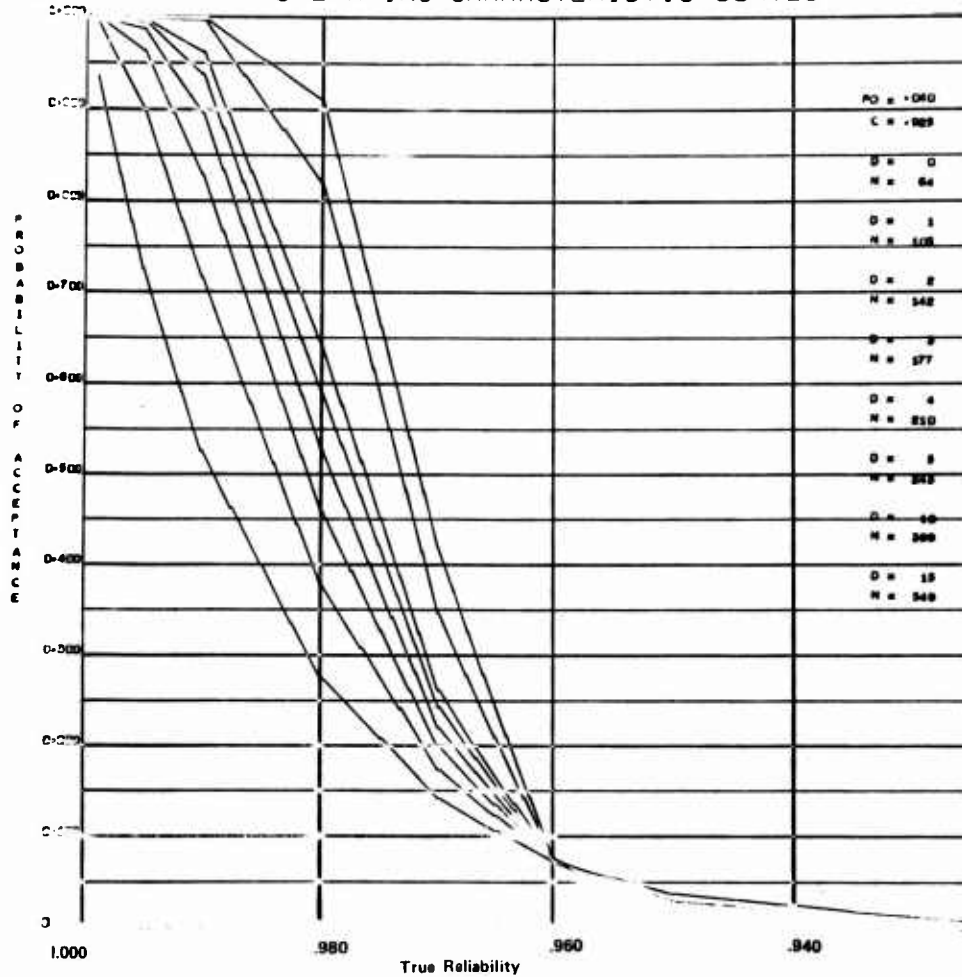
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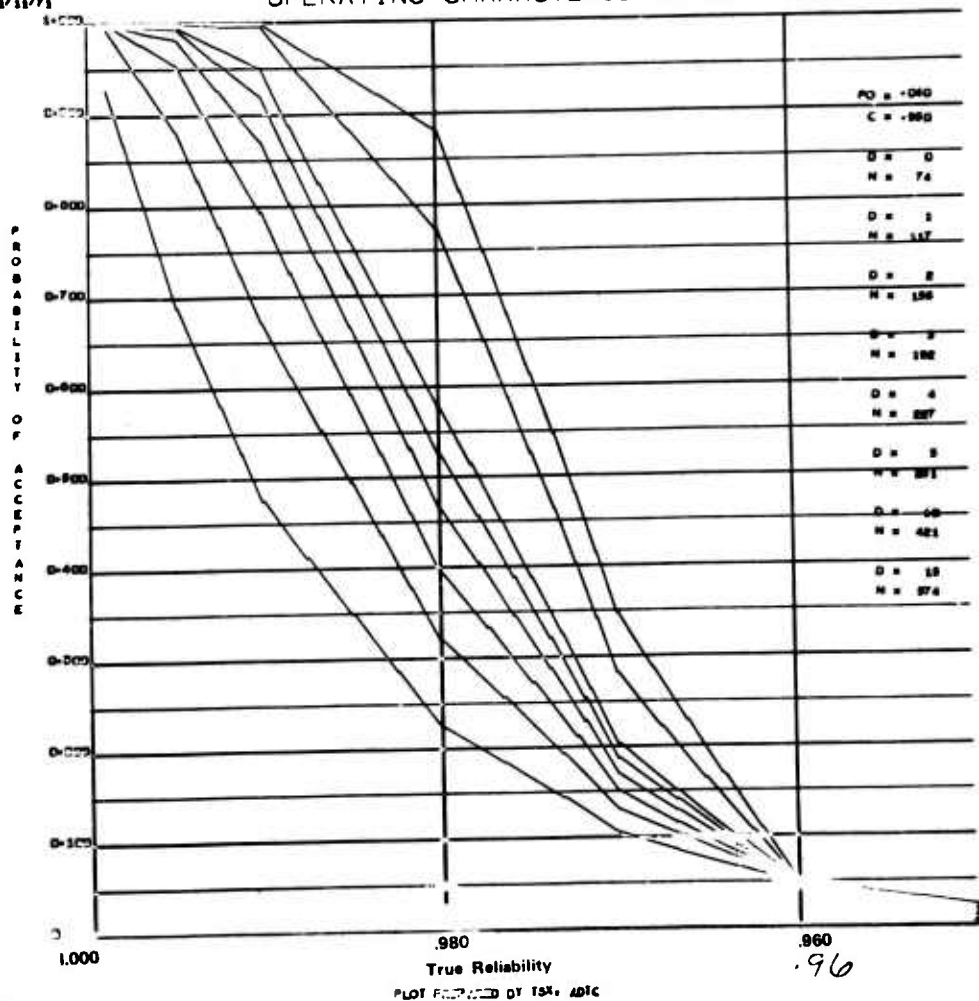
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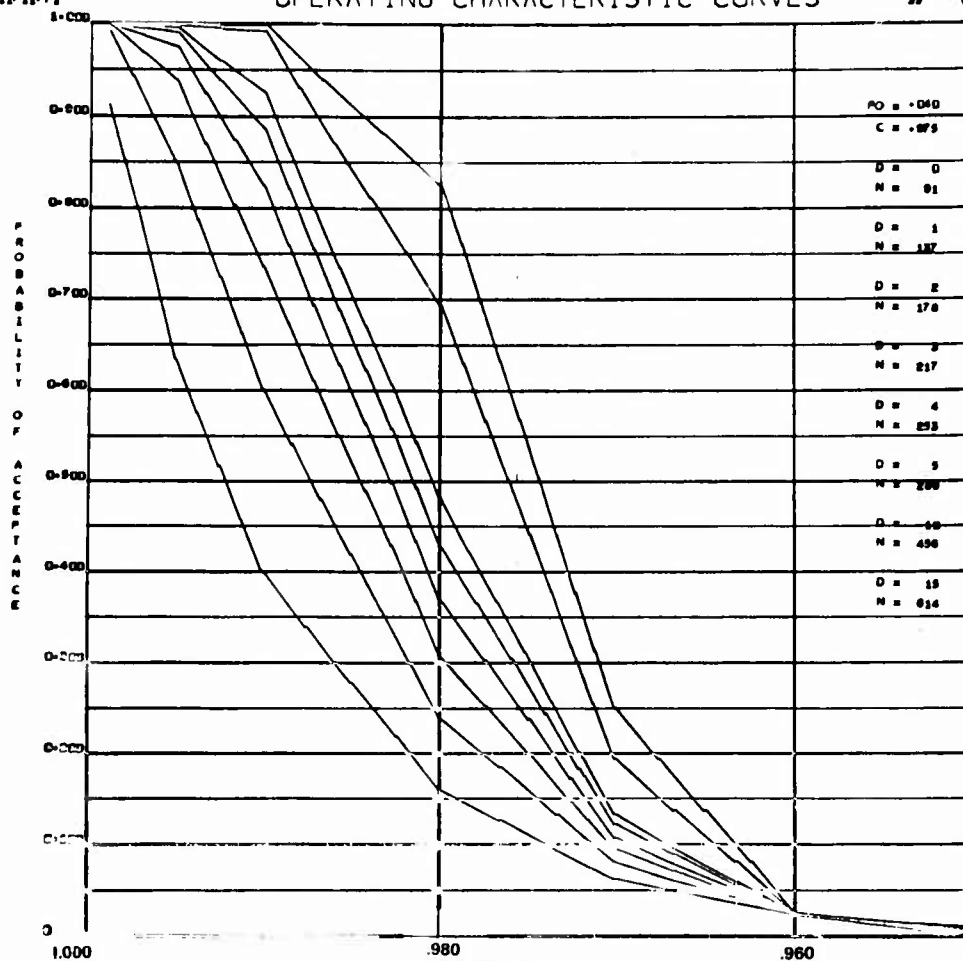
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OPERATING CHARACTERISTIC CURVES

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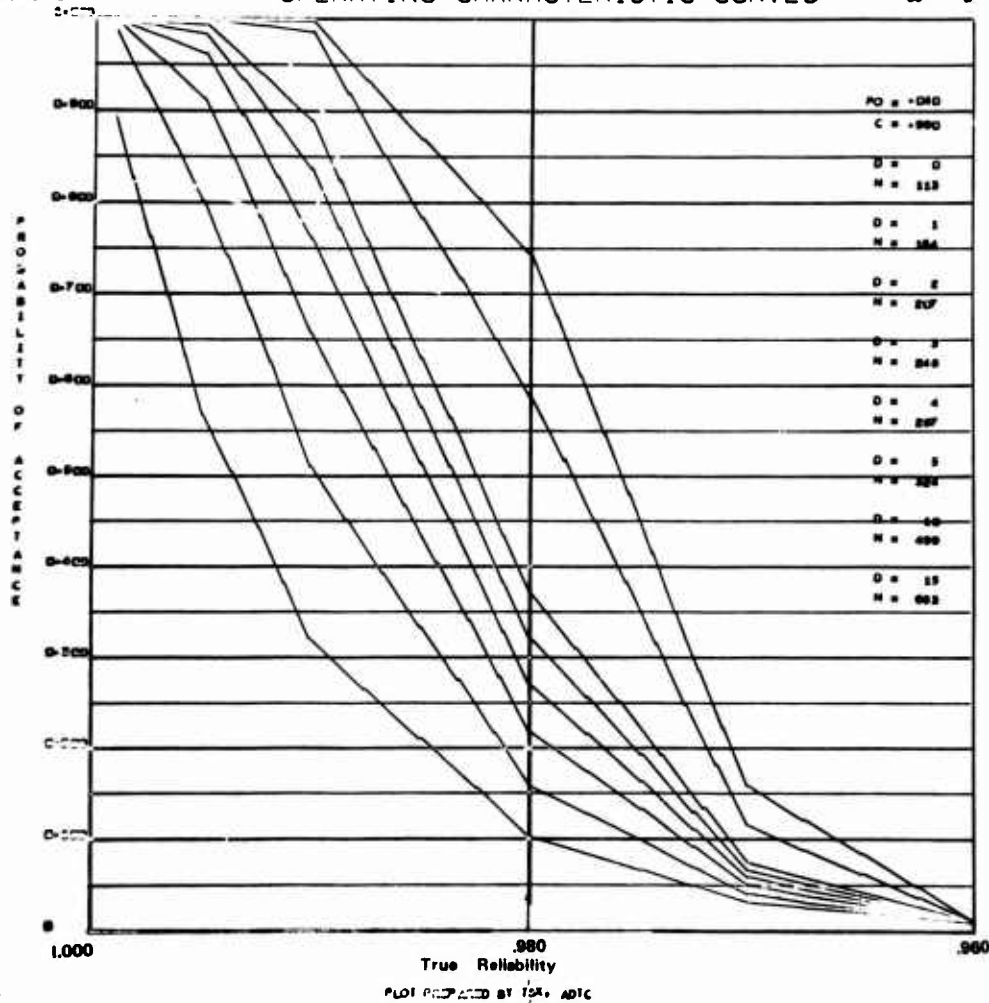


True Reliability
PLOT PREPARED BY ISM, ADTC

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OPERATING CHARACTERISTIC CURVES

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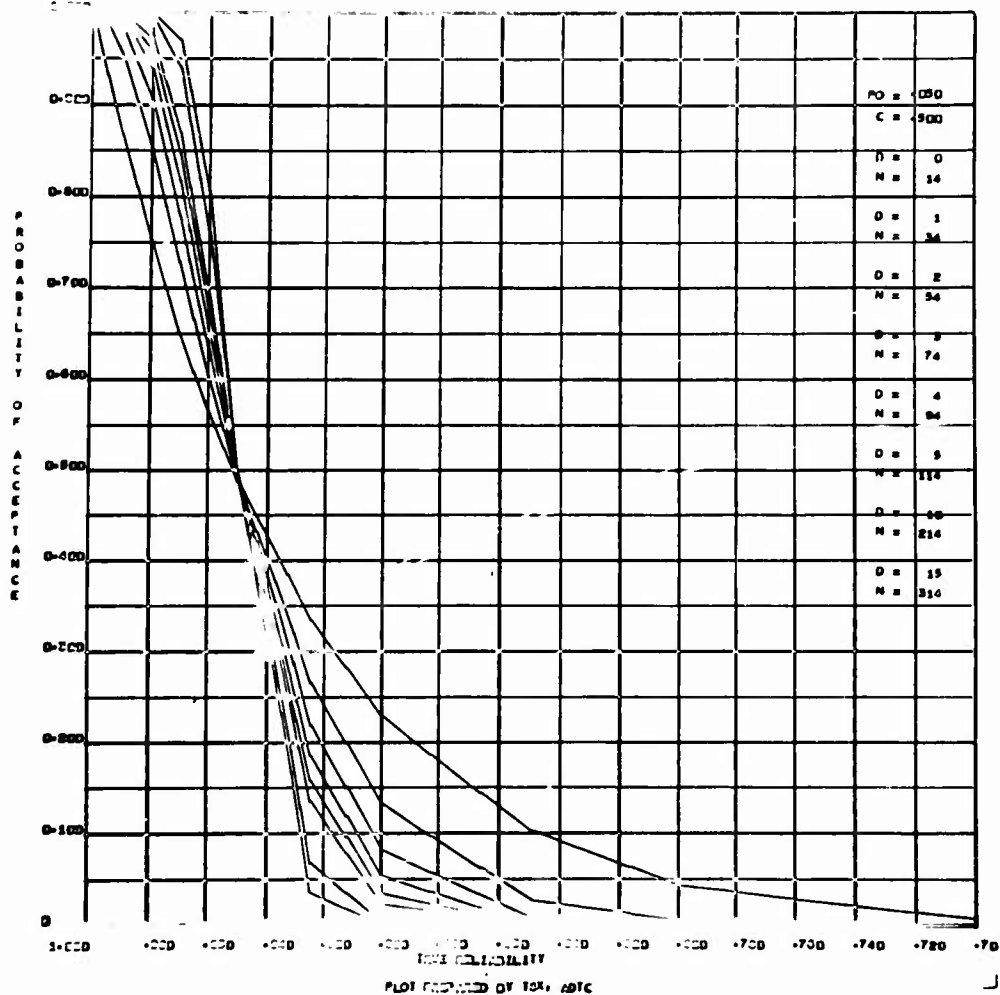


APPENDIX V
OPERATING CHARACTERISTIC
CURVES ($p_0 = .050$)

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OPERATING CHARACTERISTIC CURVES

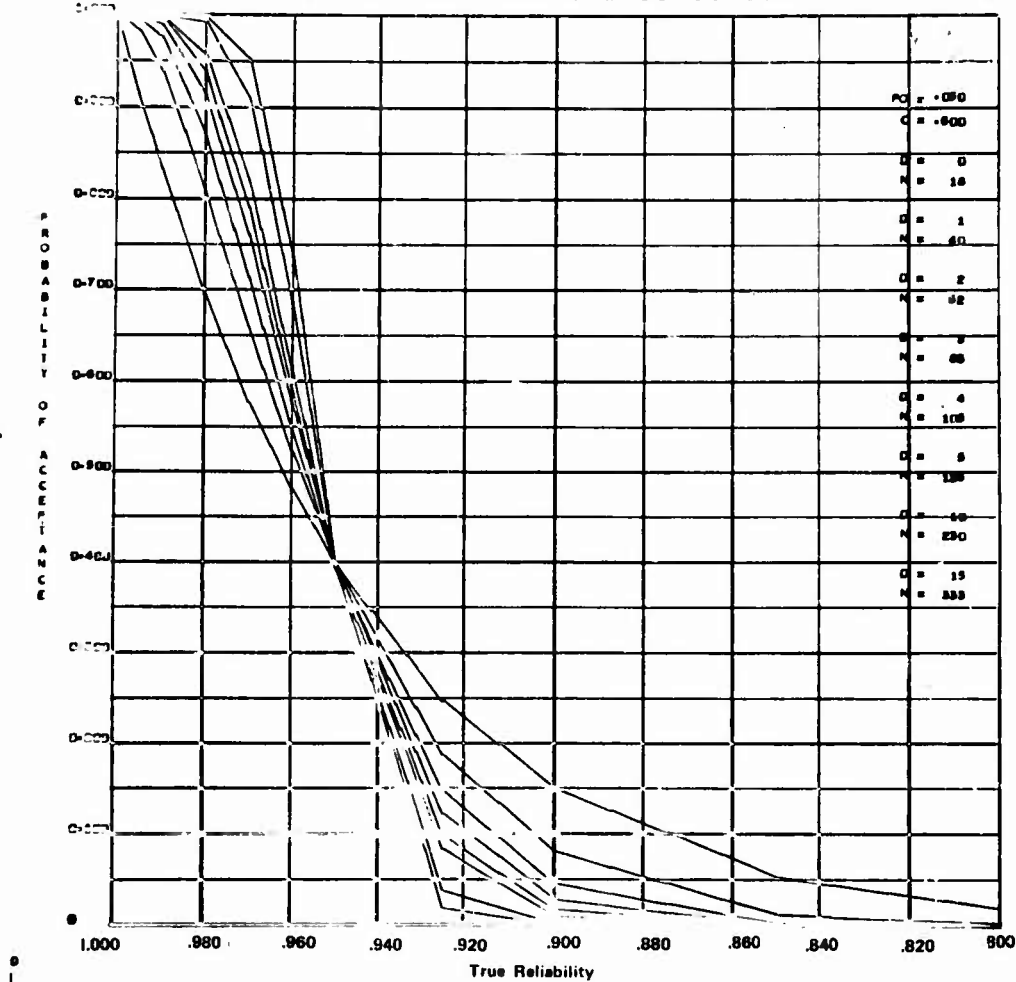
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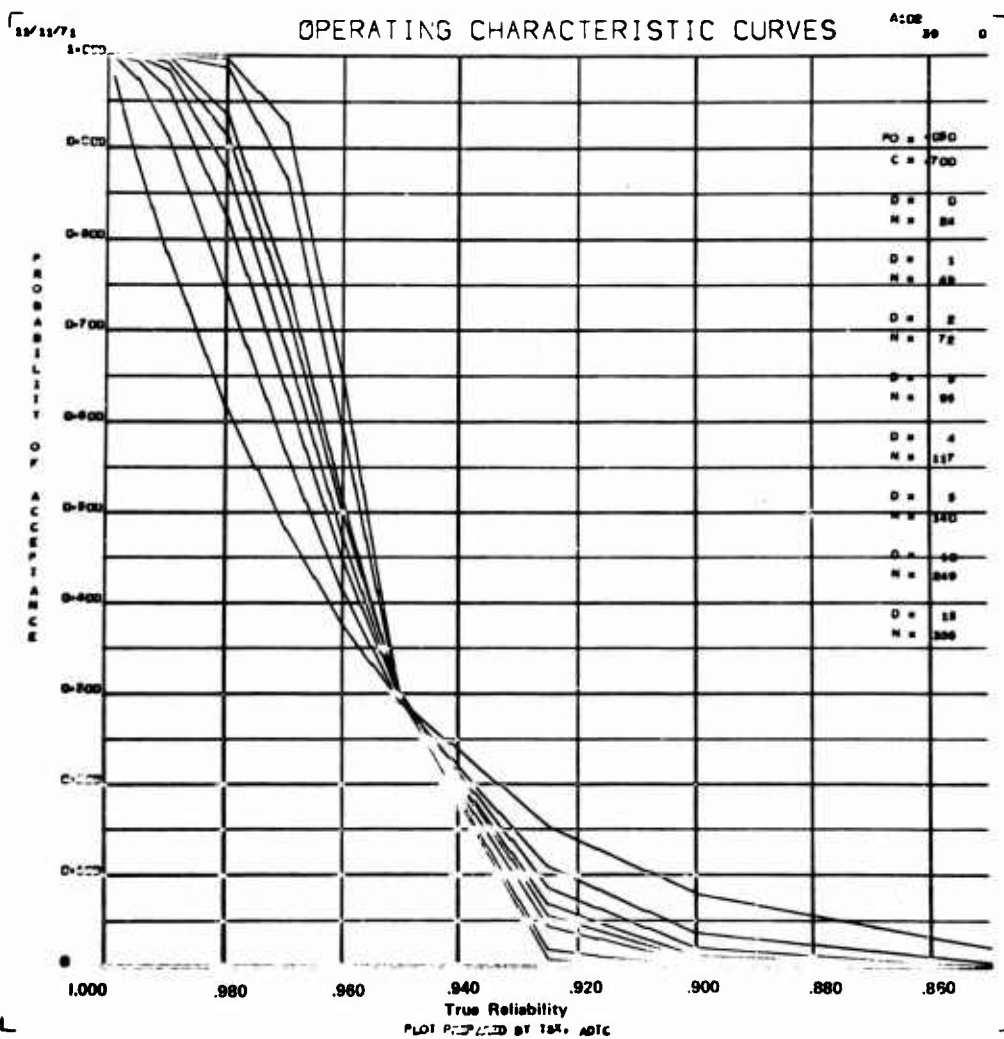


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OPERATING CHARACTERISTIC CURVES

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OPERATING CHARACTERISTIC CURVES

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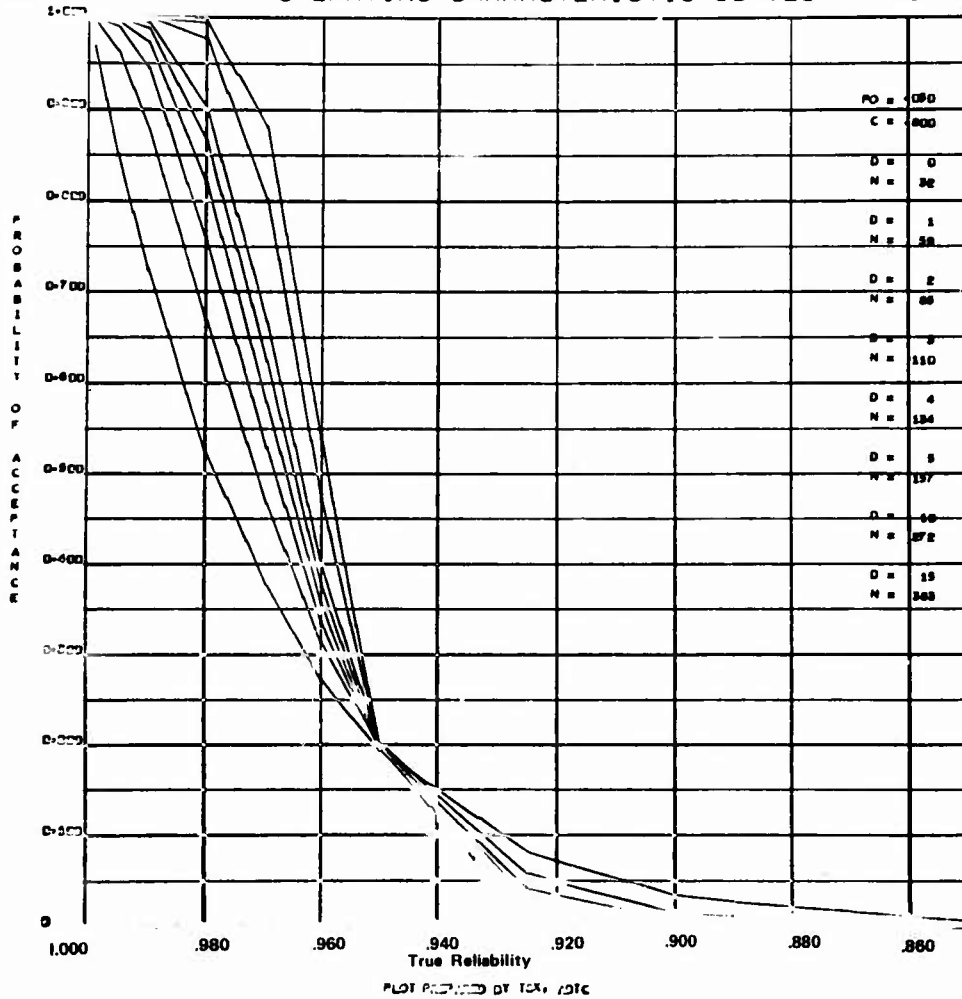
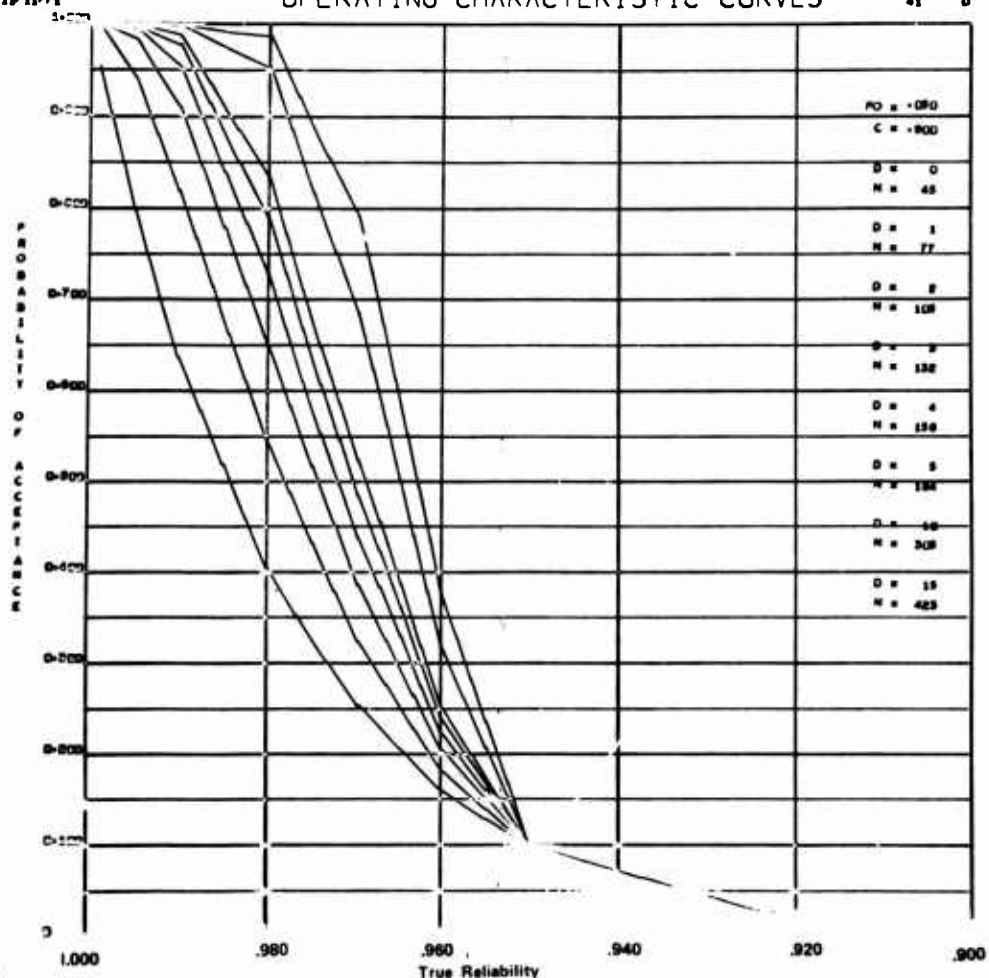


Figure 1

OPERATING CHARACTERISTIC CURVES

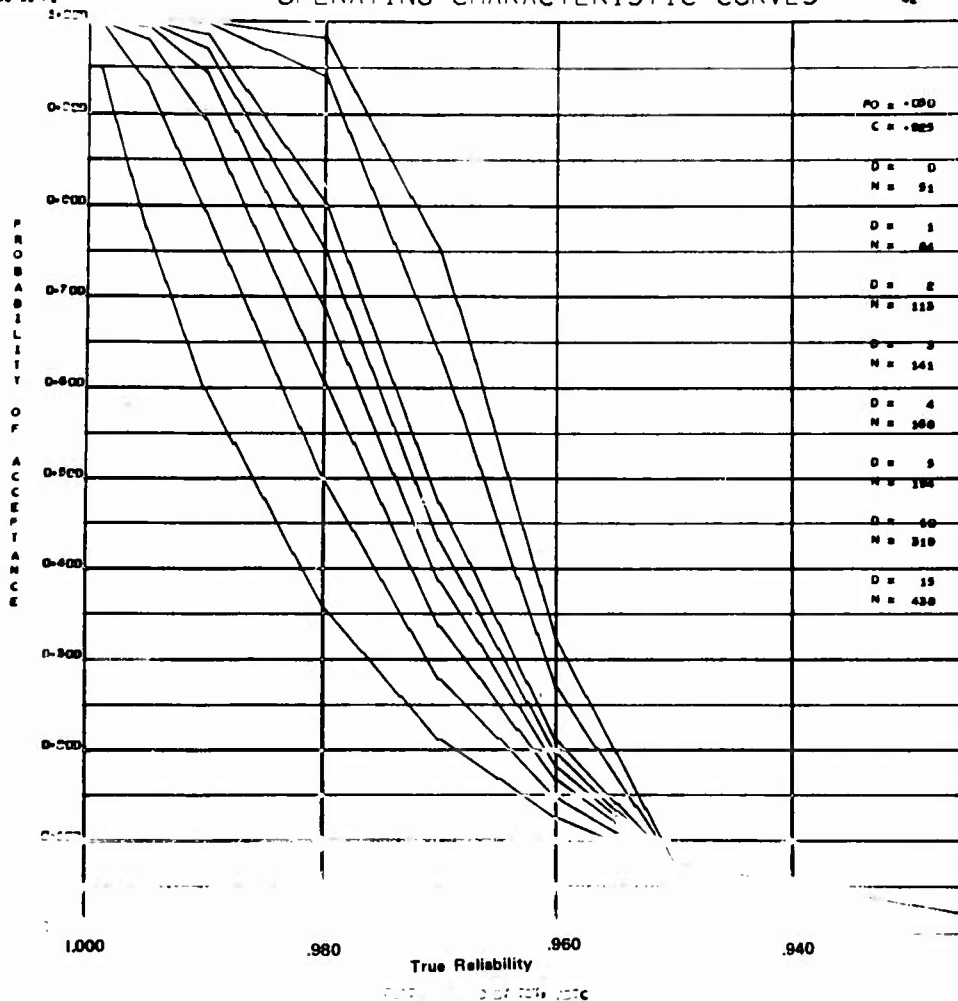
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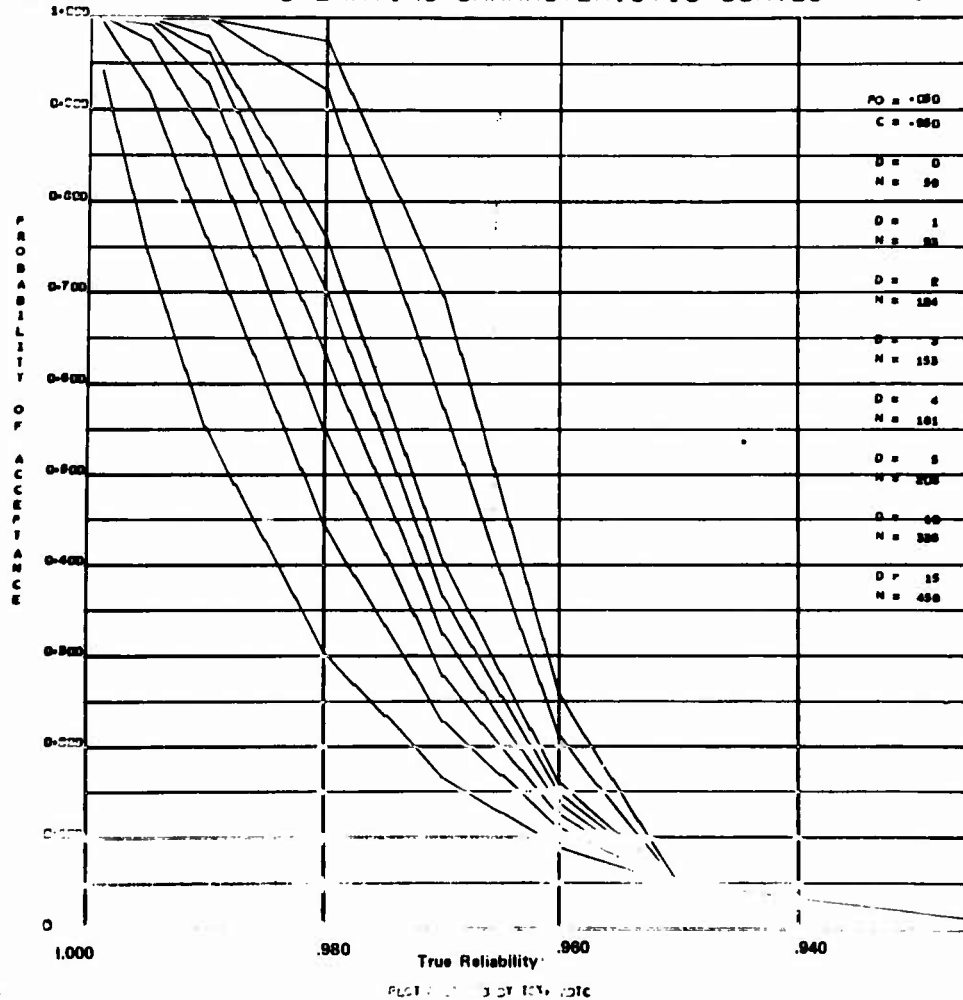
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OPERATING CHARACTERISTIC CURVES

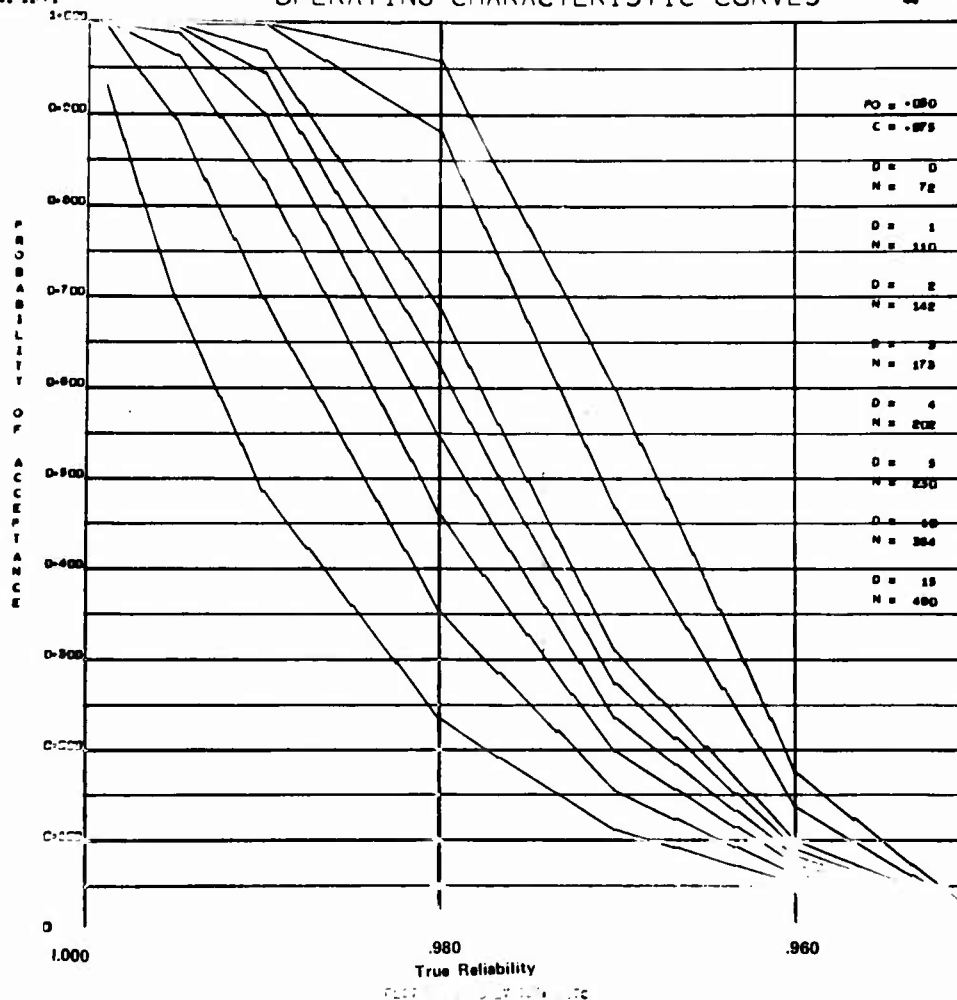
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OPERATING CHARACTERISTIC CURVES

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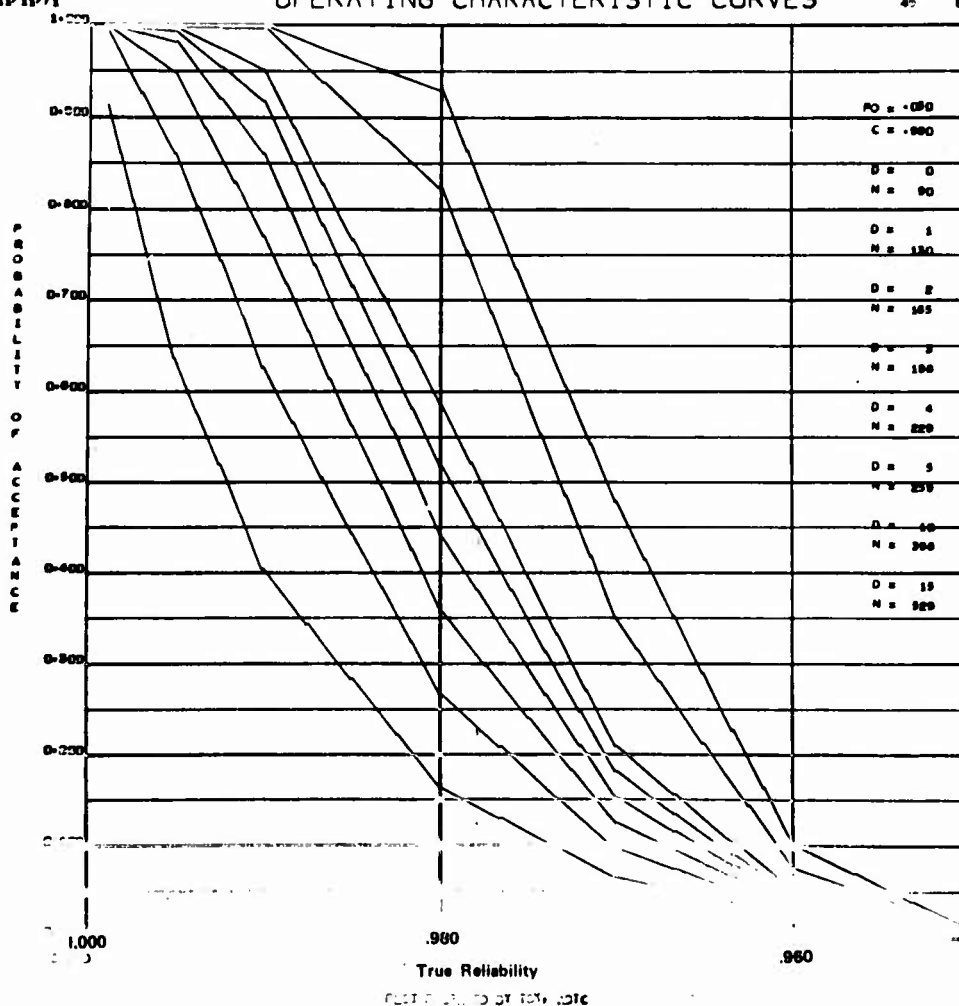


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OPERATING CHARACTERISTIC CURVES

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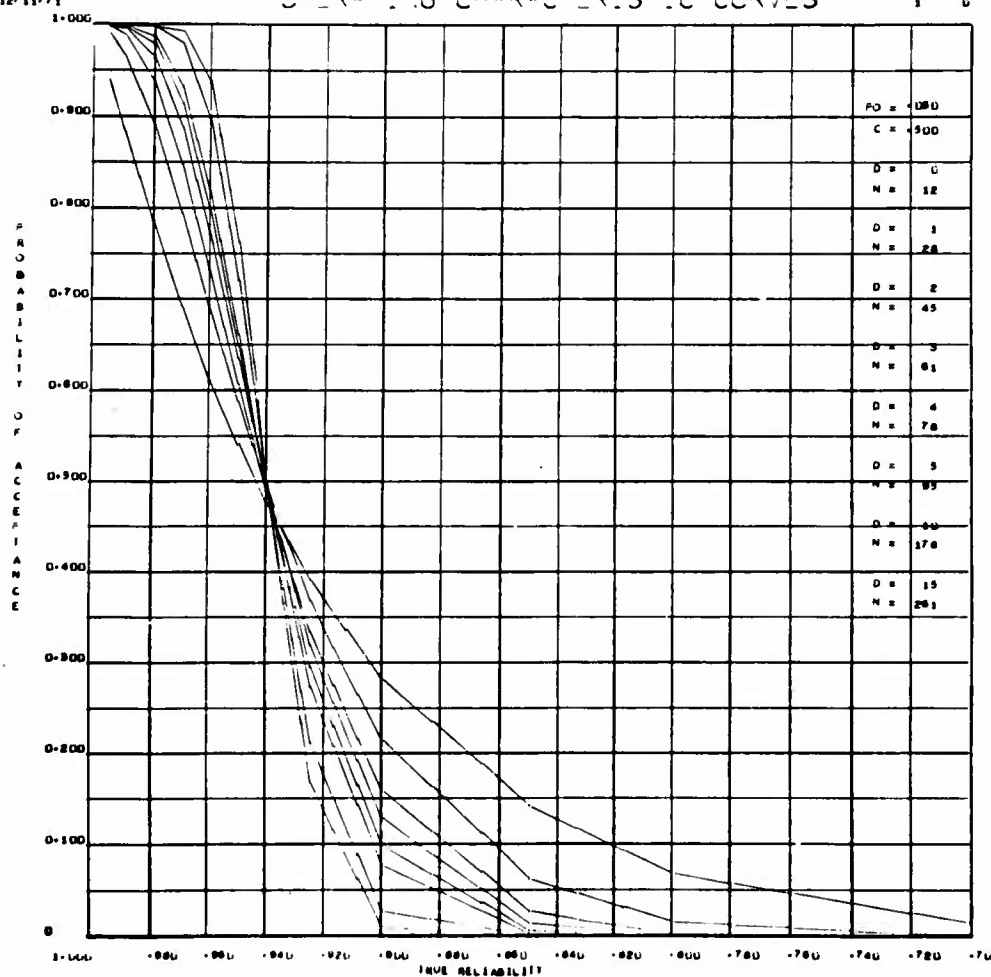
APPENDIX VI
OPERATING CHARACTERISTIC
CURVES ($p_0 = .060$)

12/11/71

OPERATING CHARACTERISTIC CURVES

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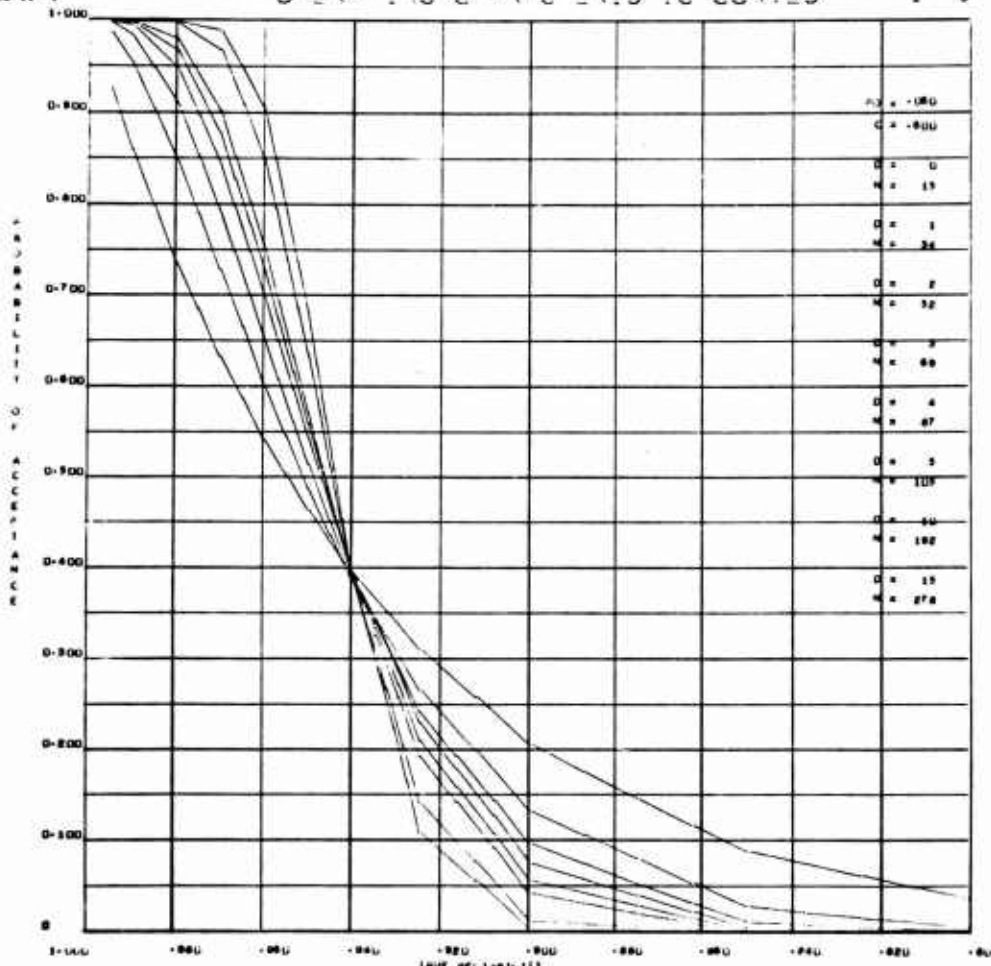
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OPERATING CHARACTERISTIC CURVES

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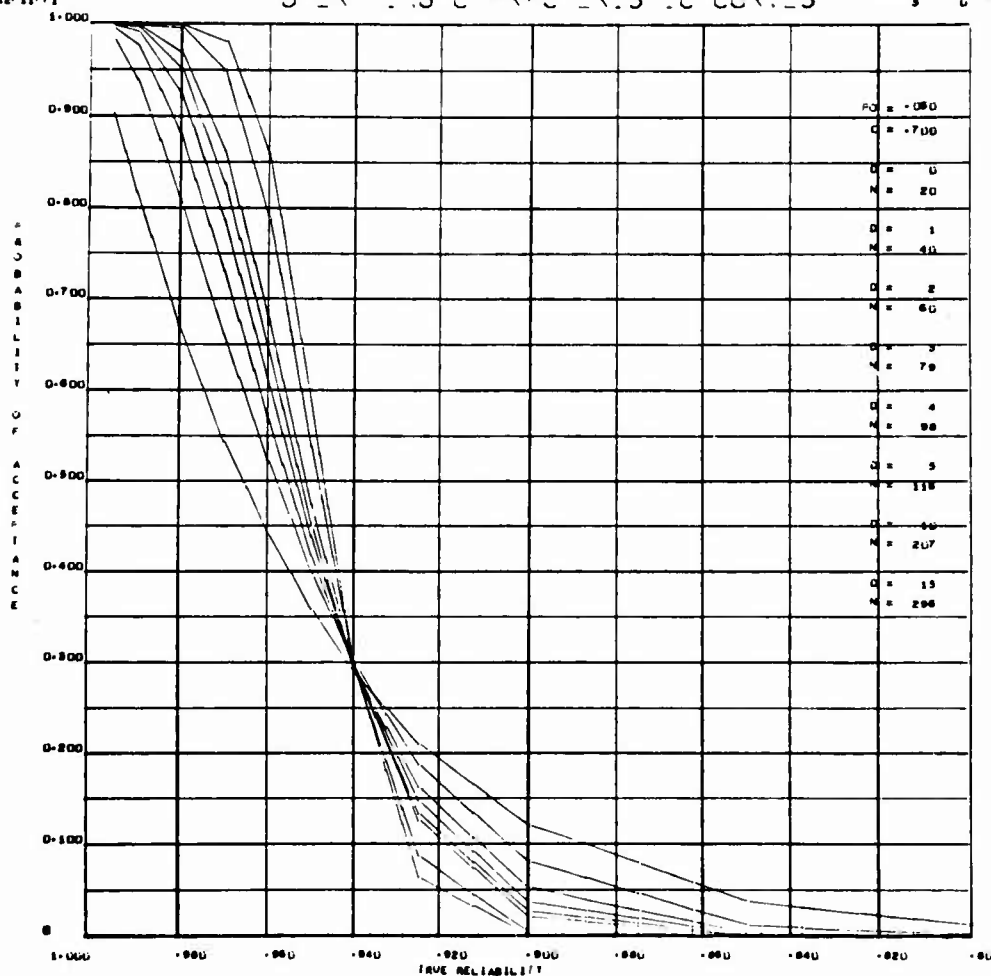
PL01 PREPARED BY 154, ADTC

12/11/71

OPERATING CHARACTERISTIC CURVES

A114

67

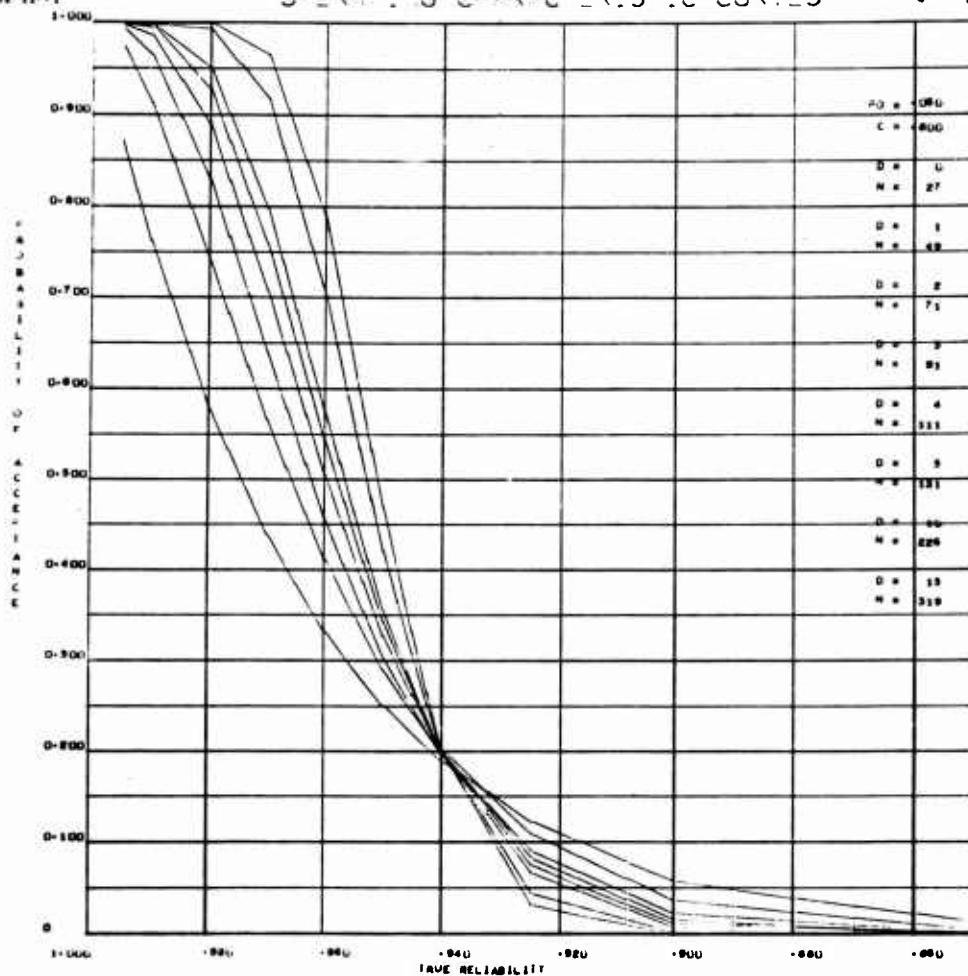


PLT PREPARED BY 1341 ADTC

12/11/71

OPERATING CHARACTERISTIC CURVES

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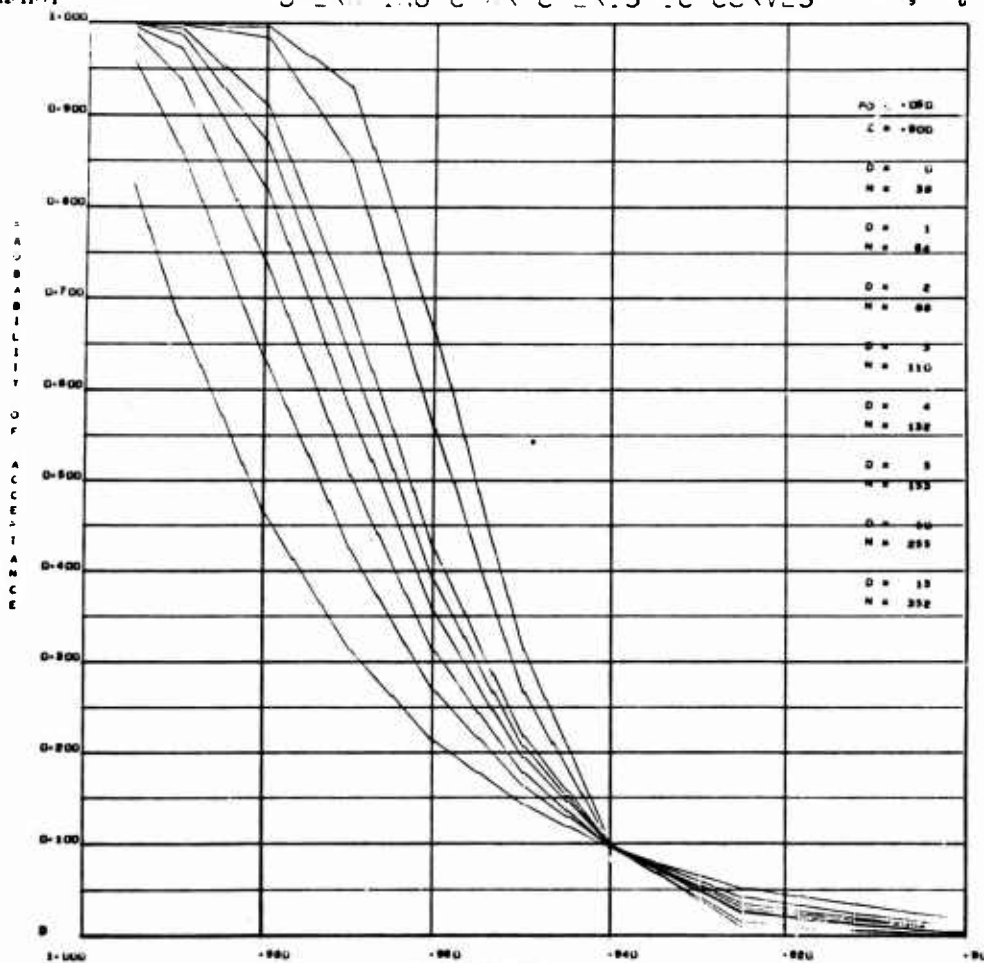


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OPERATING CHARACTERISTIC CURVES

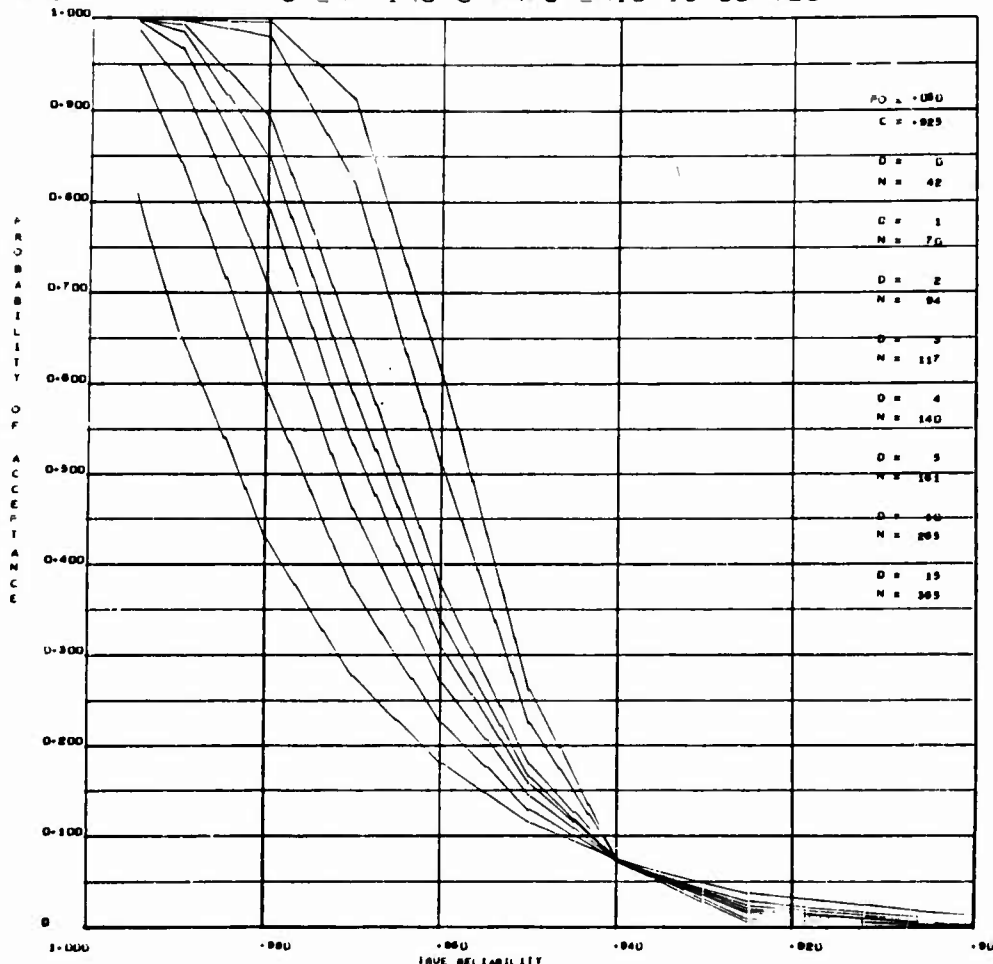
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12/11/71

OPERATING CHARACTERISTIC CURVES

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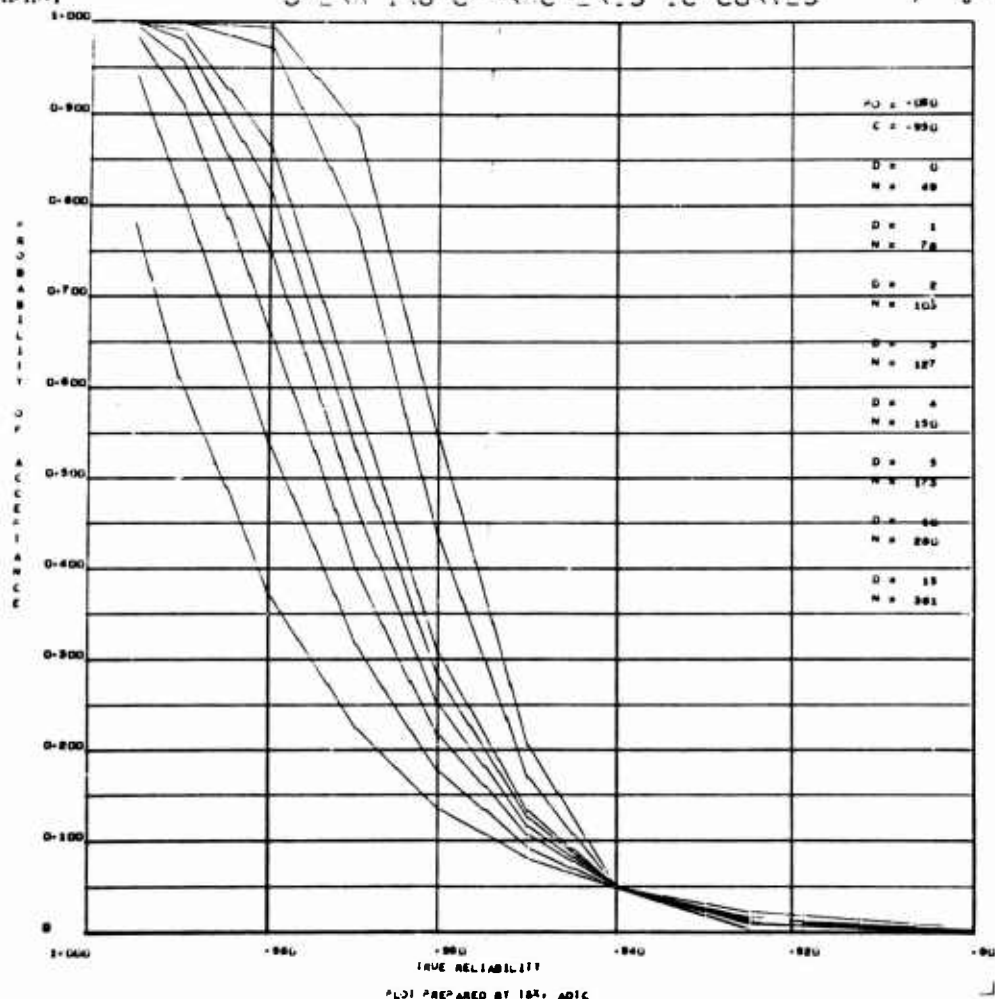
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12/11/73

OPERATING CHARACTERISTIC CURVES

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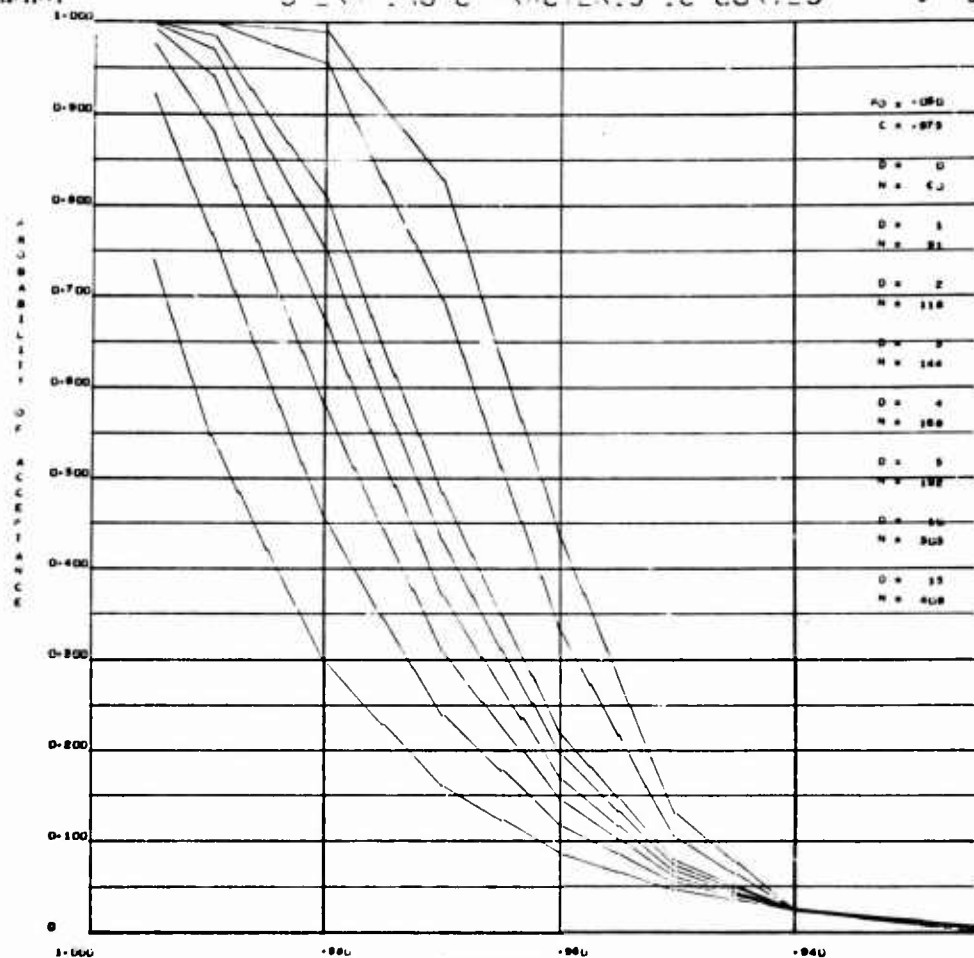
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127 11/73

OPERATING CHARACTERISTIC CURVES

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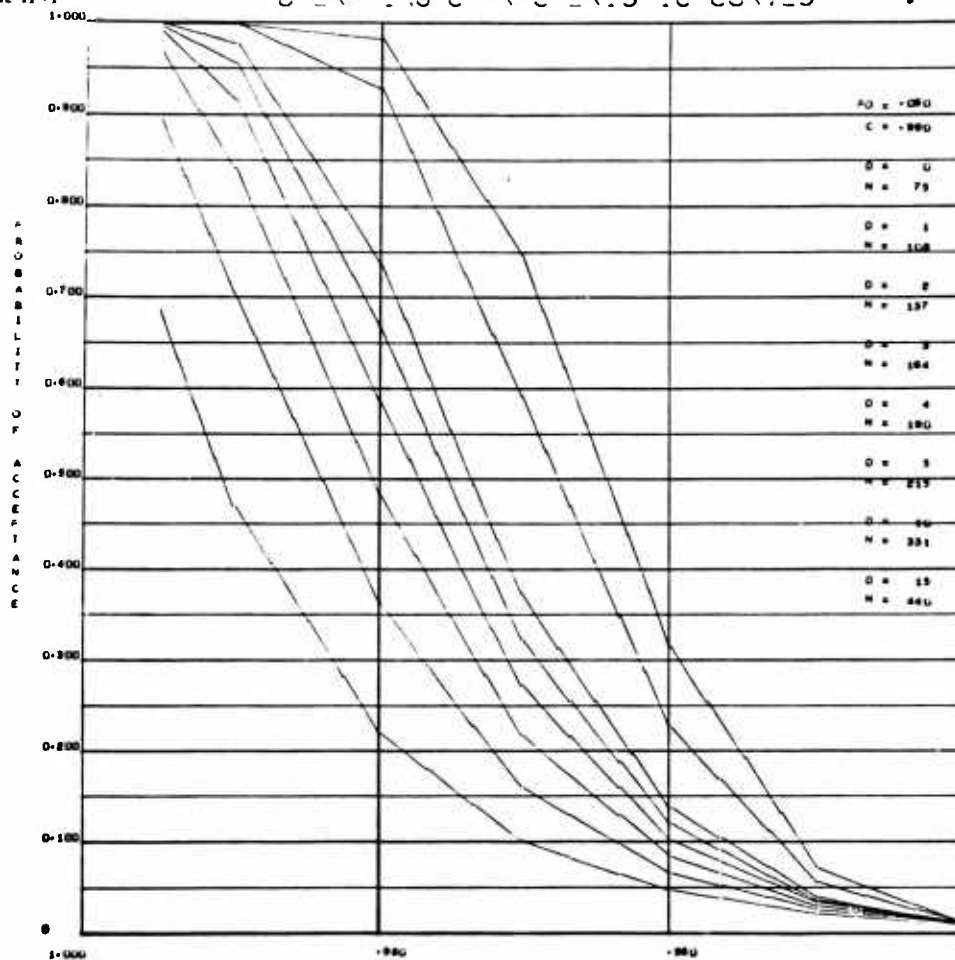


TRUE RELIABILITY
PLOT PREPARED BY 184, ADIC

12/11/71

OPERATING CHARACTERISTIC CURVES

A314



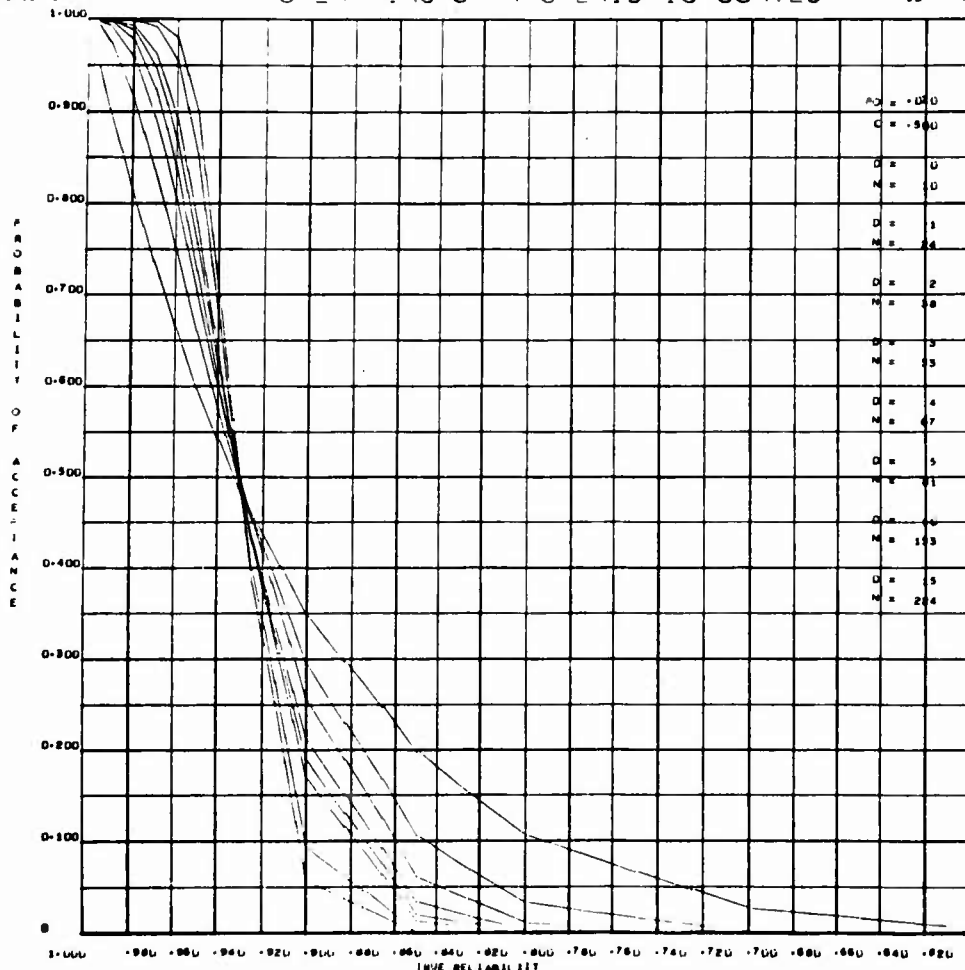
TRUE RELIABILITY
PLOT PREPARED BY 181, ADIC

APPENDIX VII
OPERATING CHARACTERISTIC
CURVES ($p_0 = .070$)

12/11/71

OPERATING CHARACTERISTIC CURVES

A114 10 07



PLOT PREPARED BY 164, ADIC

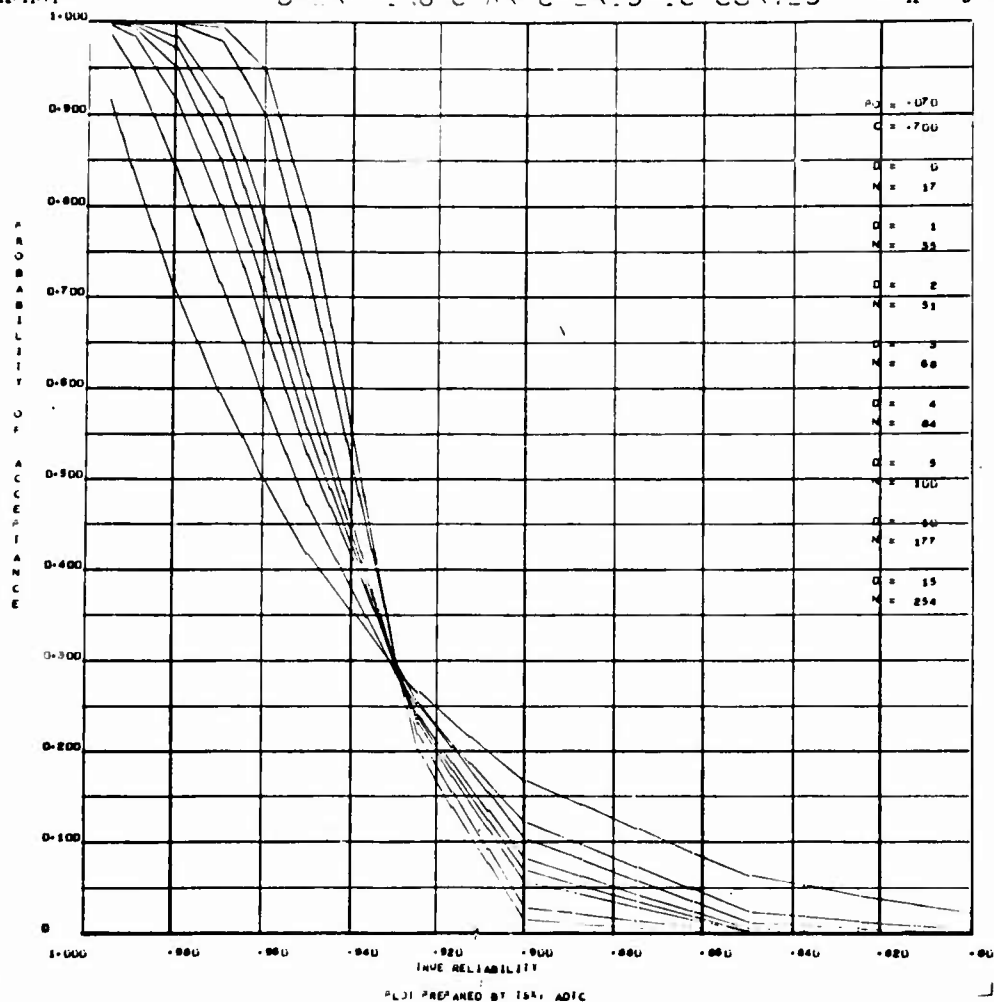
12/11/71

OPERATING CHARACTERISTIC CURVES

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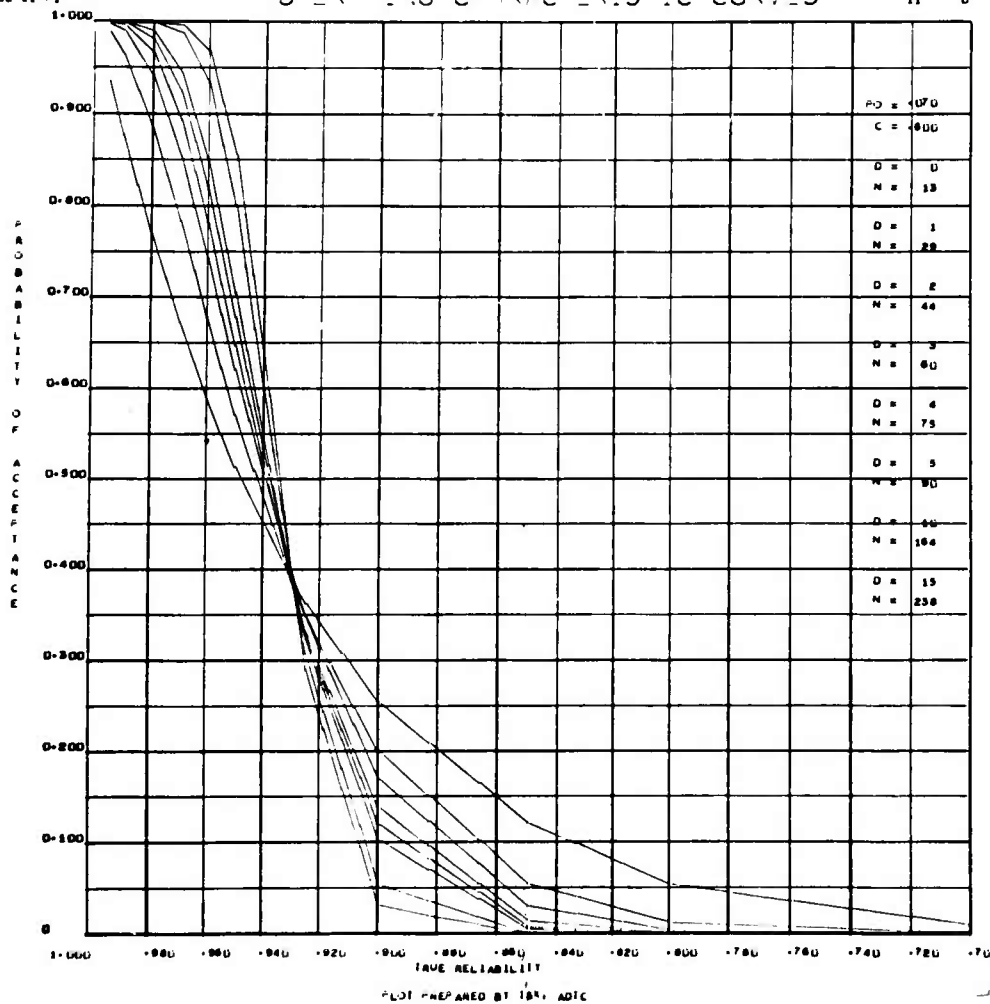
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

11

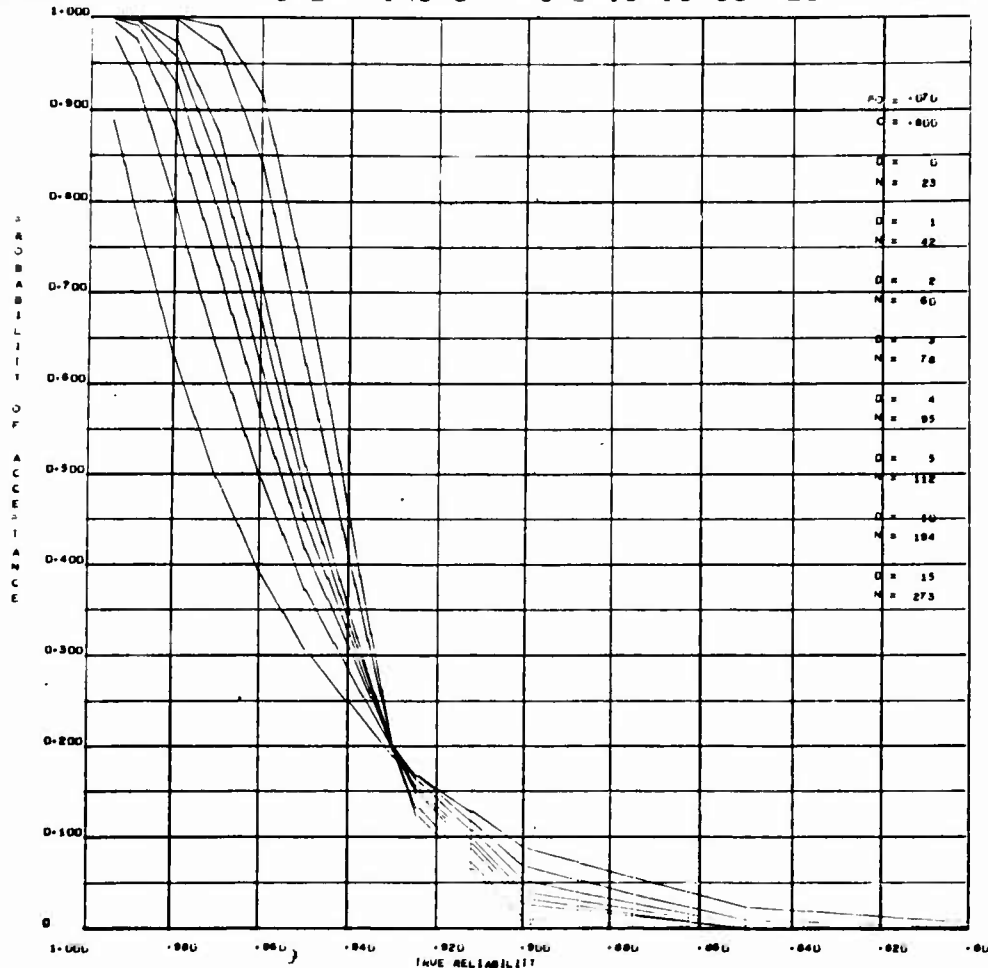
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12/11/73

OPERATING CHARACTERISTIC CURVES

A114
13



PLOT PREPARED BY 184 ADIC

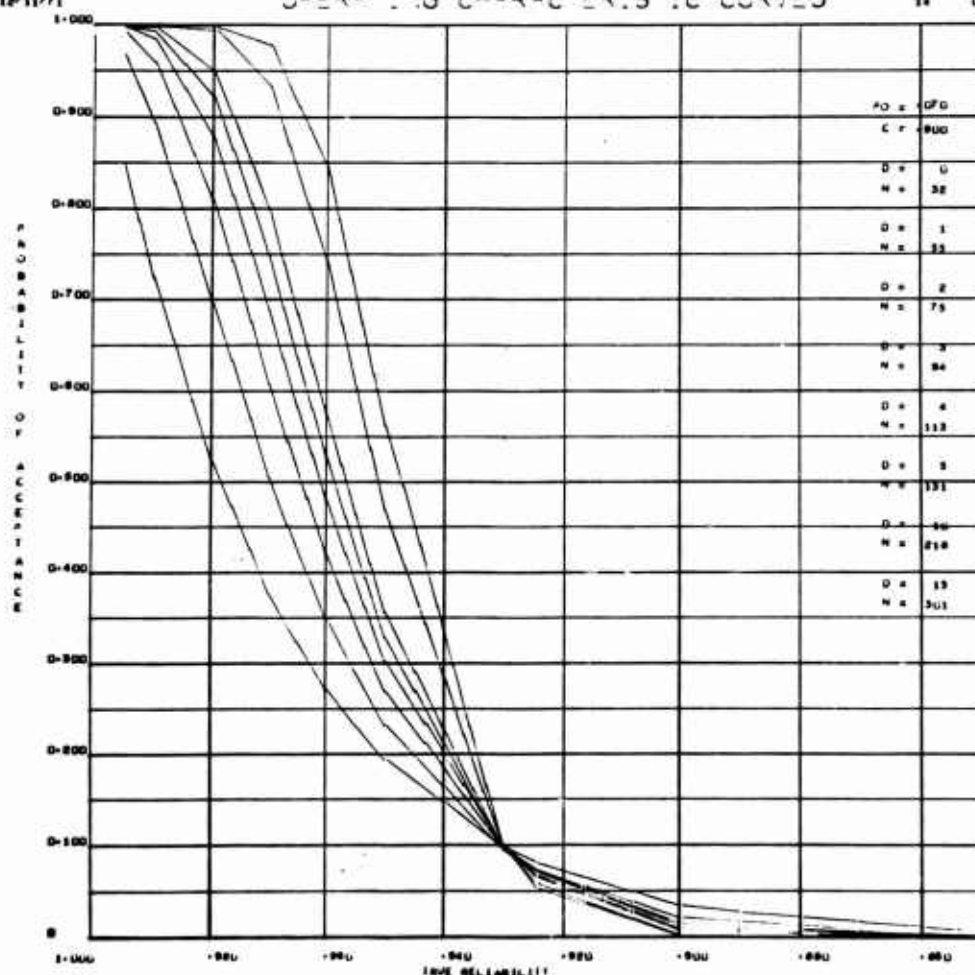
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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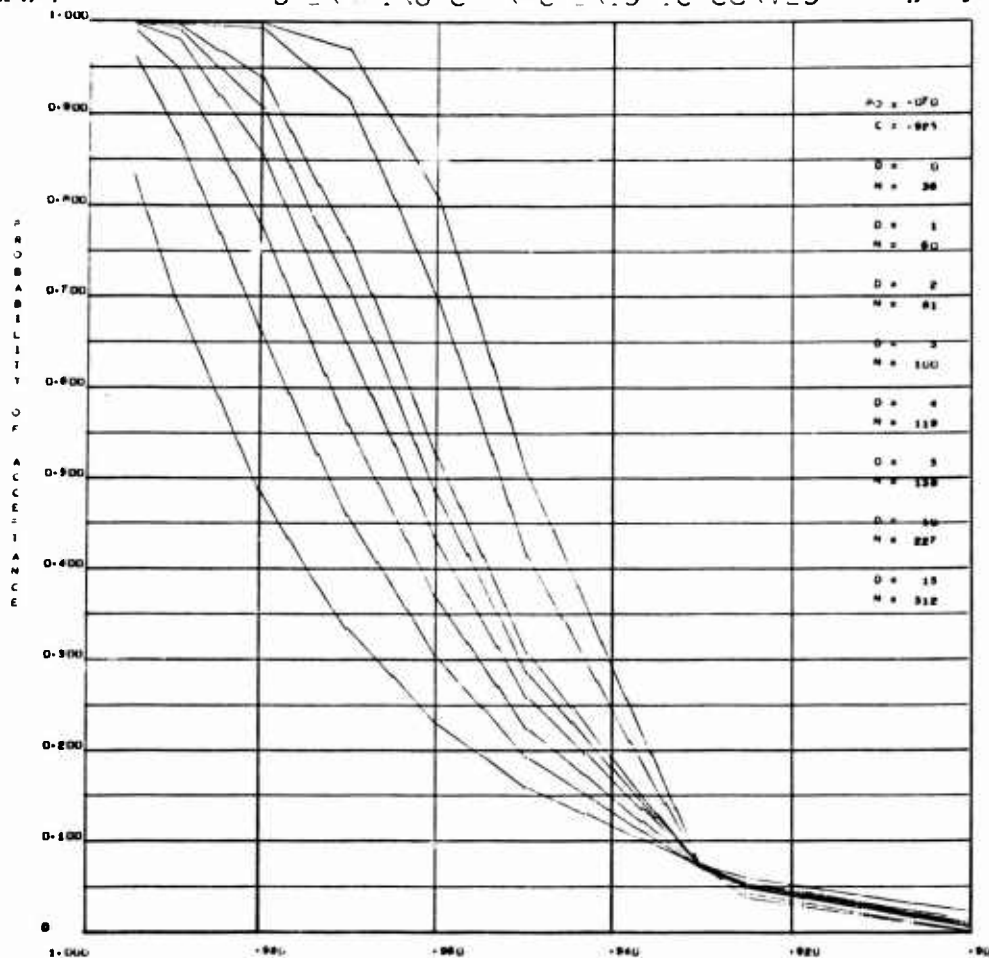
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PLT PREPARED BY 184 ADTC

12/13/71

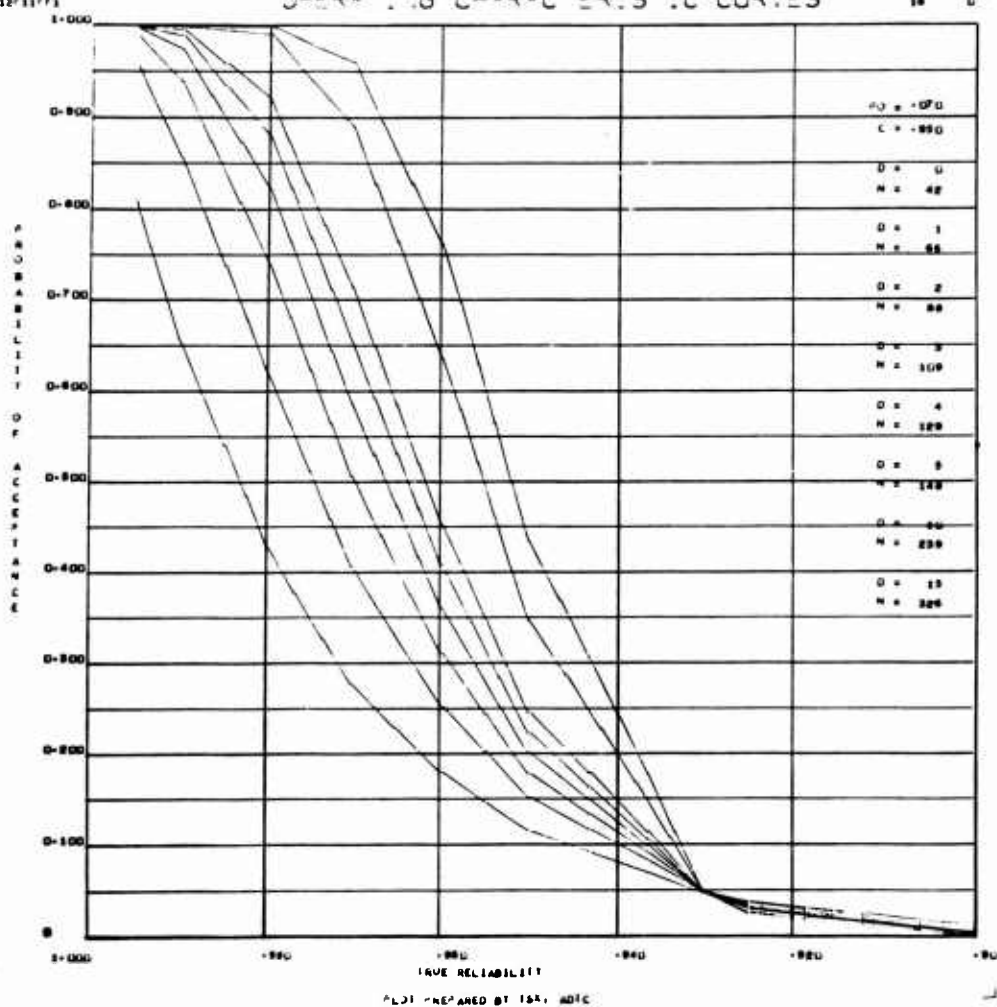
OPERATING CHARACTERISTIC CURVES

A114
15

PLOT PREPARED BY TSN, ADIC

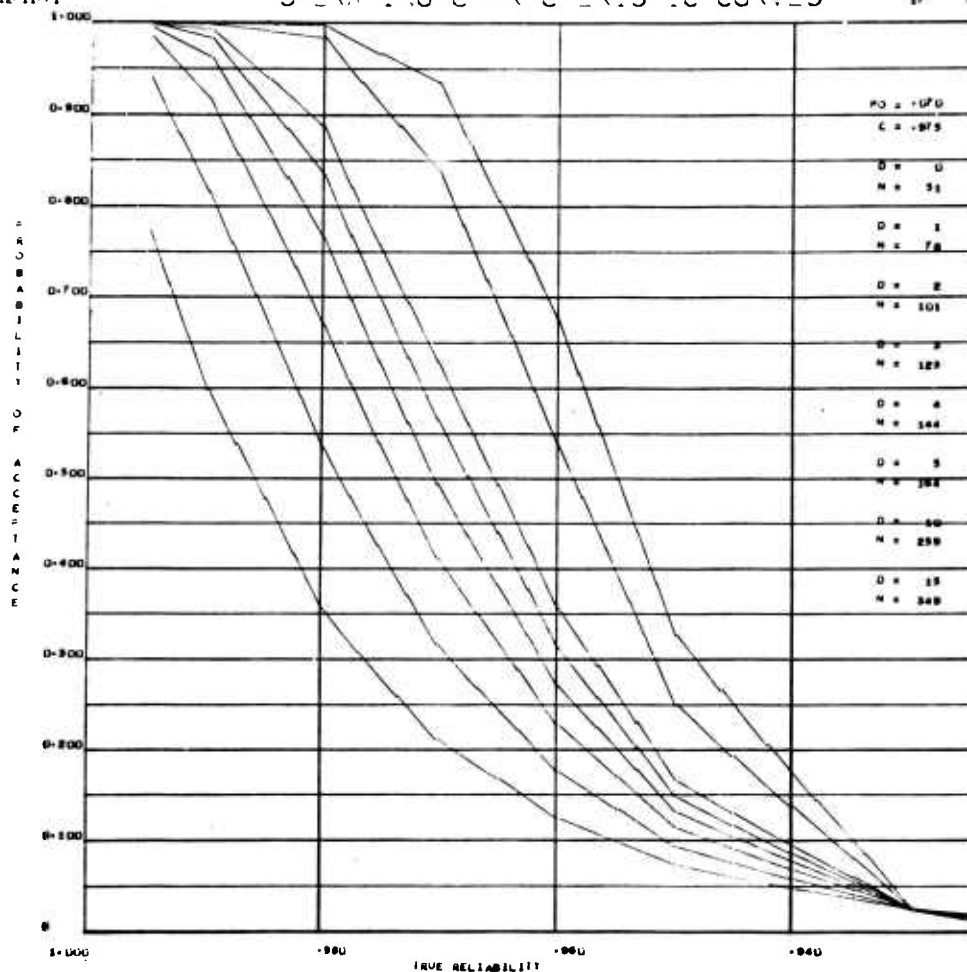
12/11/73

OPERATING CHARACTERISTIC CURVES

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12/11/71

OPERATING CHARACTERISTIC CURVES

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17 07

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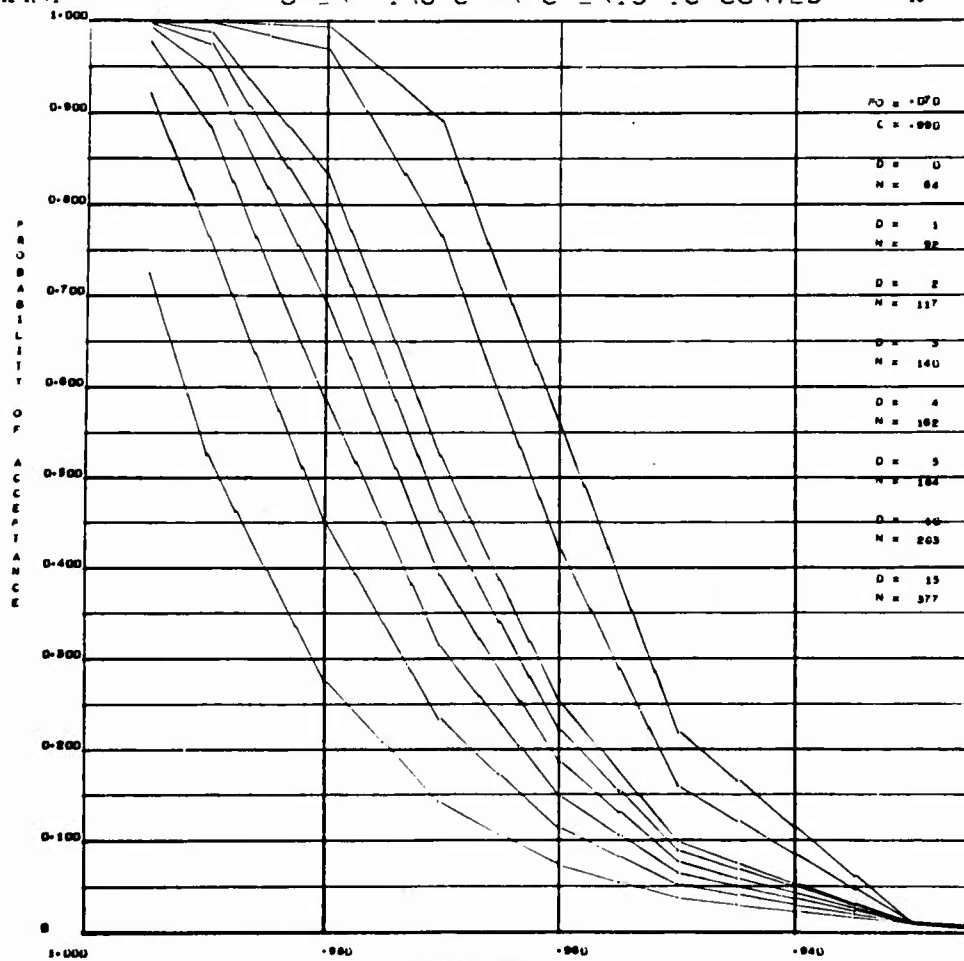
12/11/73

OPERATING CHARACTERISTIC CURVES

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TRUE RELIABILITY
PLOT PREPARED BY 164 ADIC

APPENDIX VIII
OPERATING CHARACTERISTIC
CURVES ($p_0 = .080$)

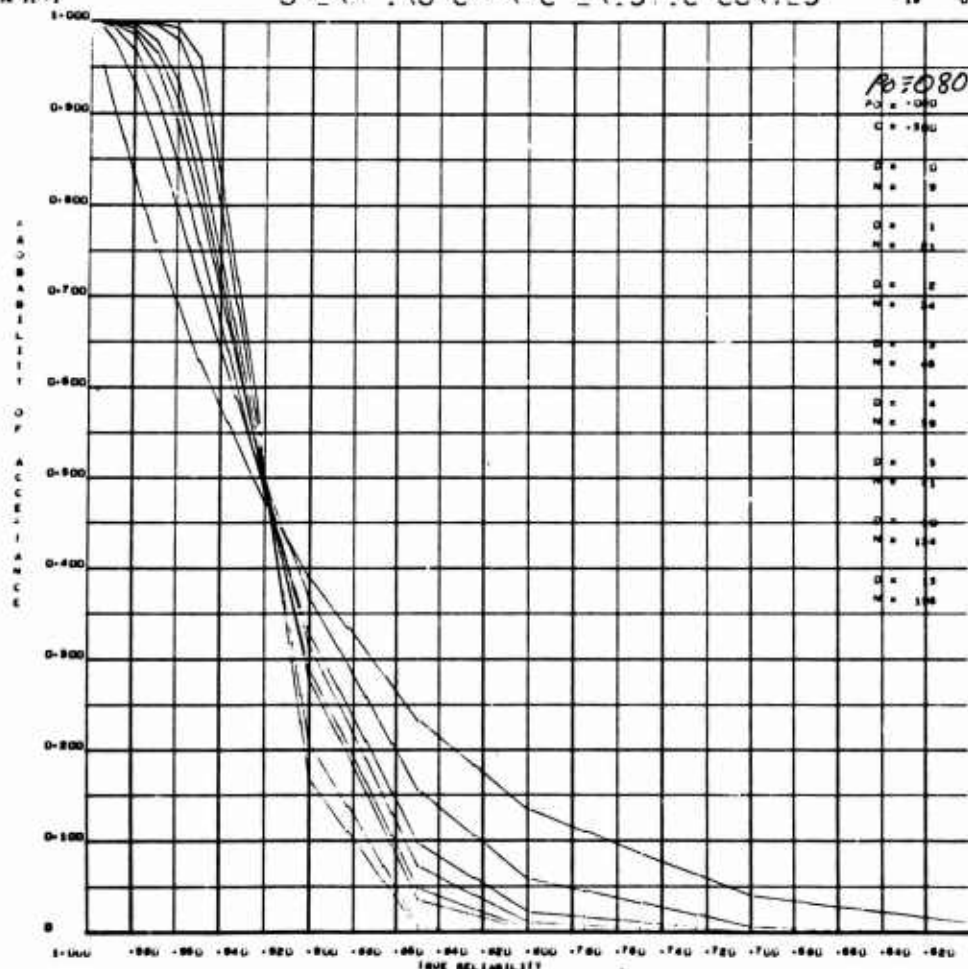
SP/11/71

OPERATING CHARACTERISTIC CURVES

A114

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NOT PREPARED BY 151: ADTC

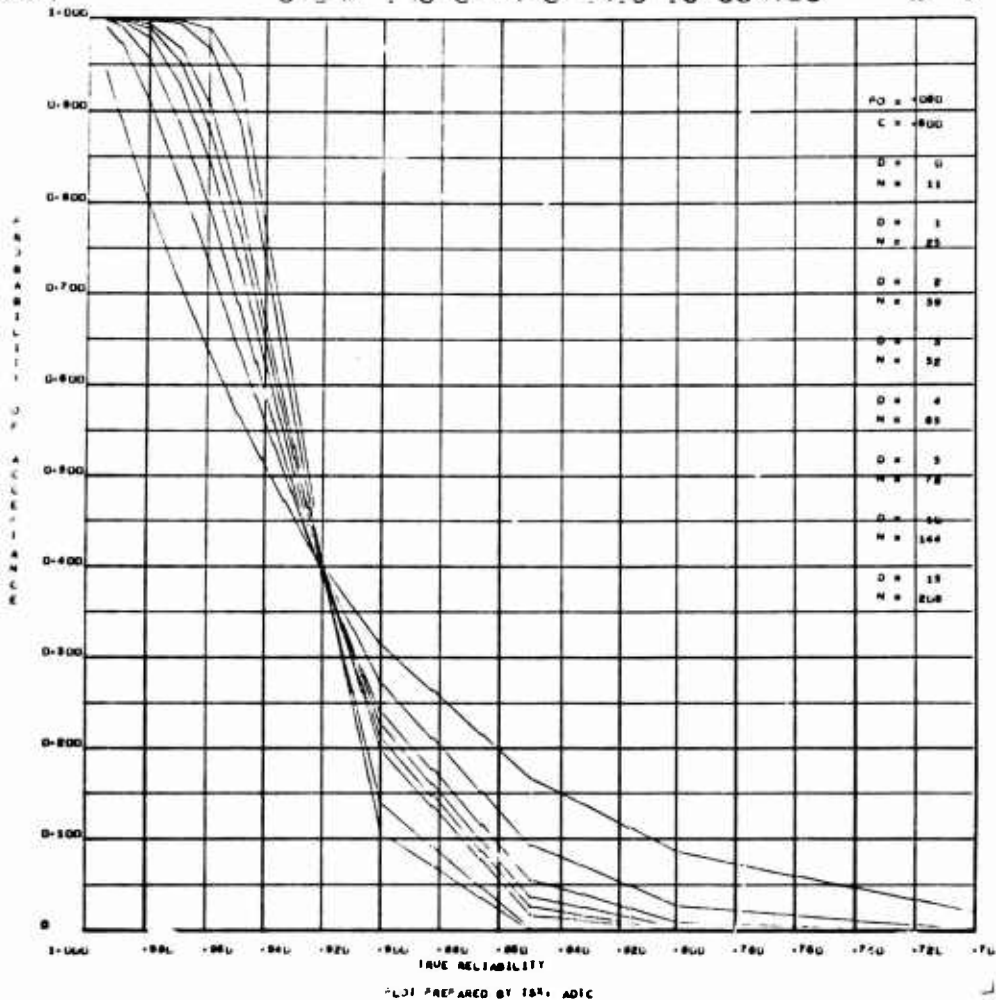
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OPERATING CHARACTERISTIC CURVES

A334

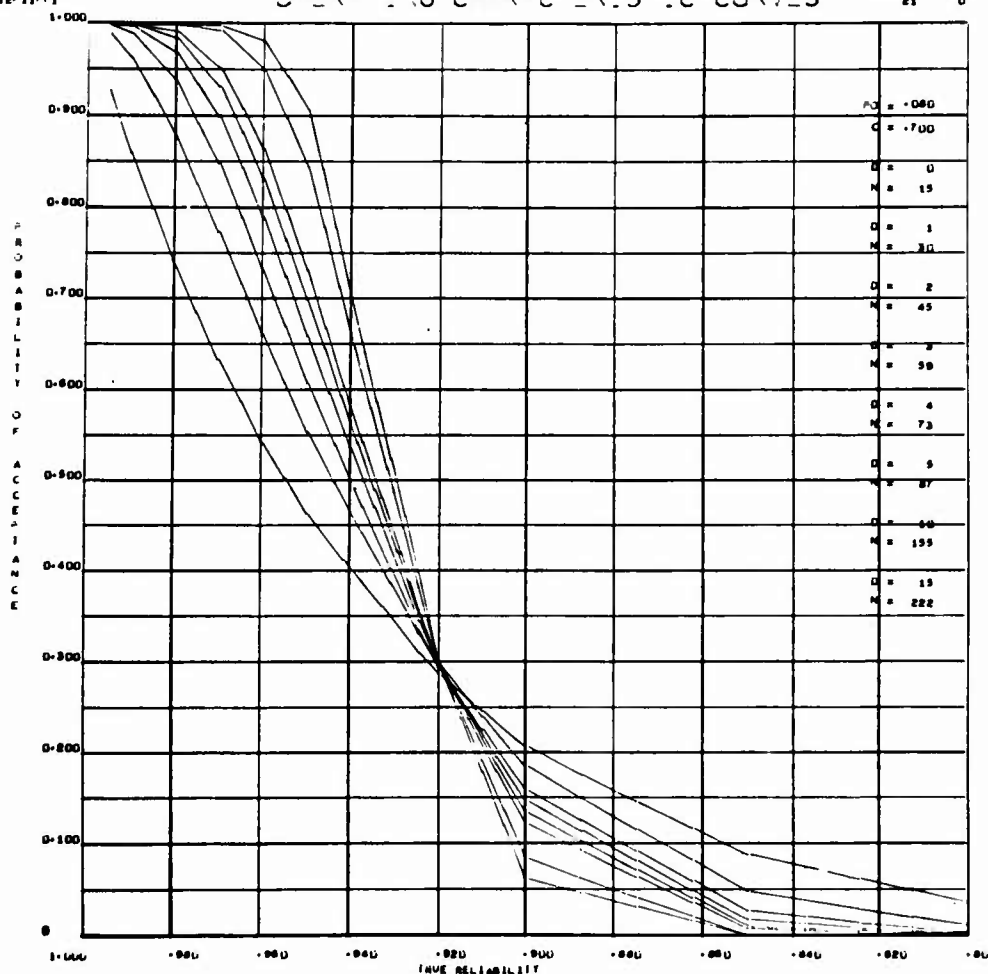
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12/11/71

OPERATING CHARACTERISTIC CURVES

A314
21

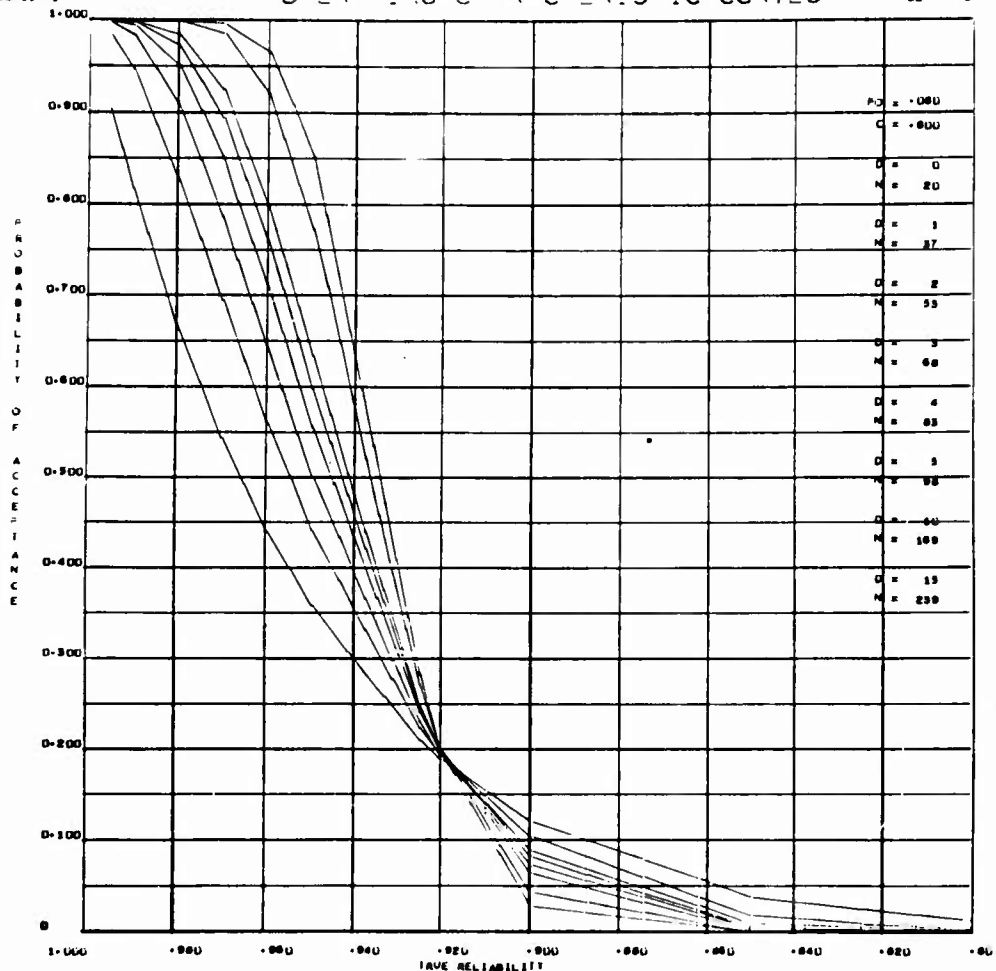
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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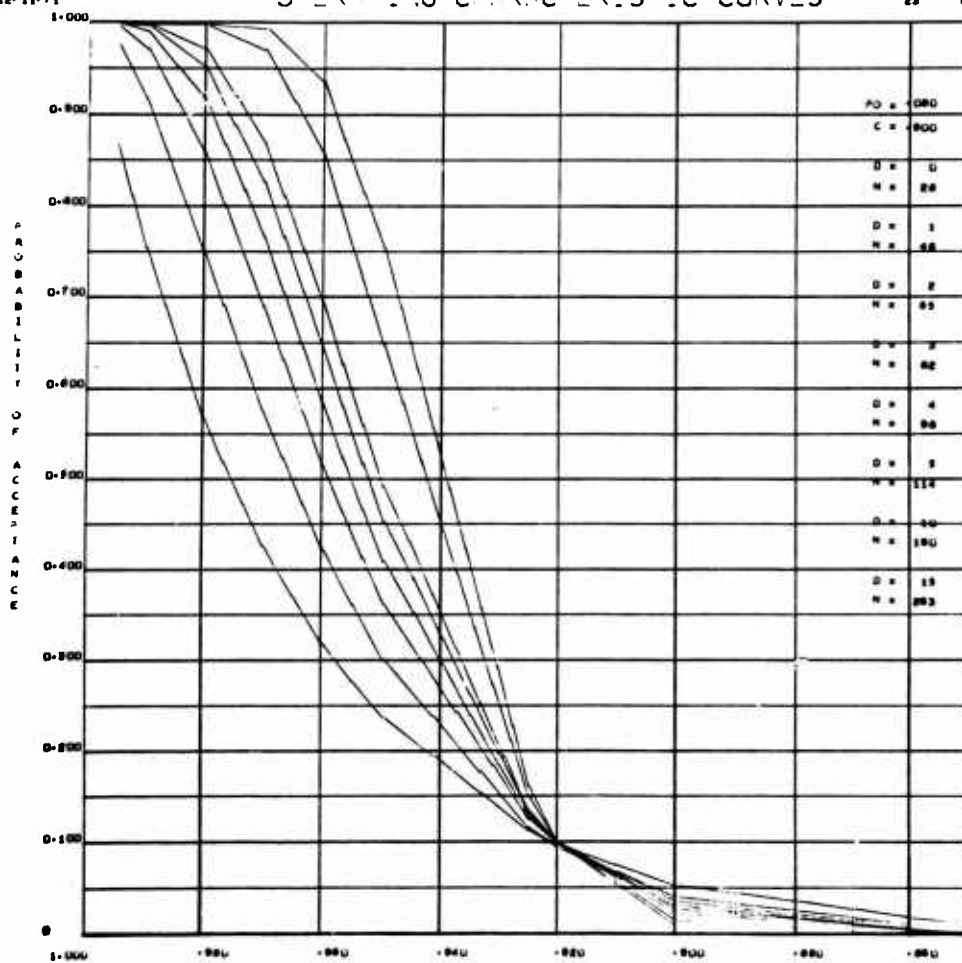
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OPERATING CHARACTERISTIC CURVES

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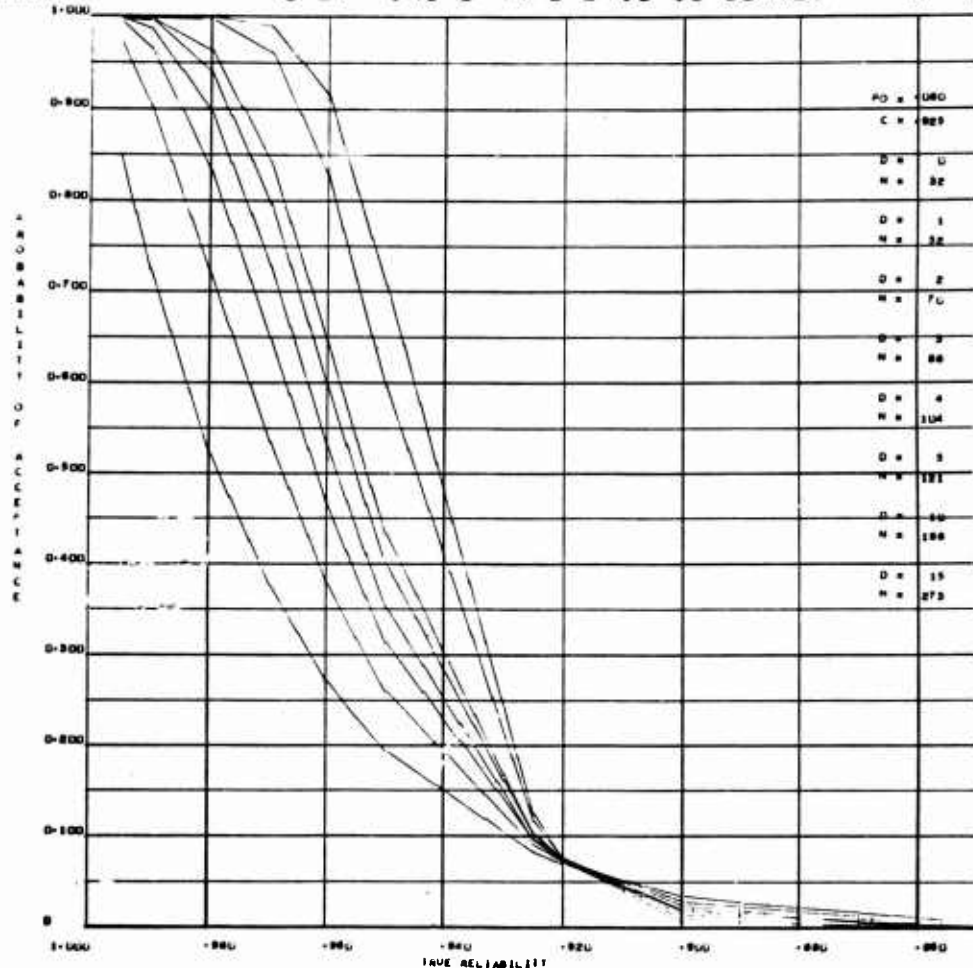


PLOT PREPARED BY IBA, ADIC

REF: 11-71

OPERATING CHARACTERISTIC CURVES

ASST 24



PLT PREPARED BY 15A, ADIC

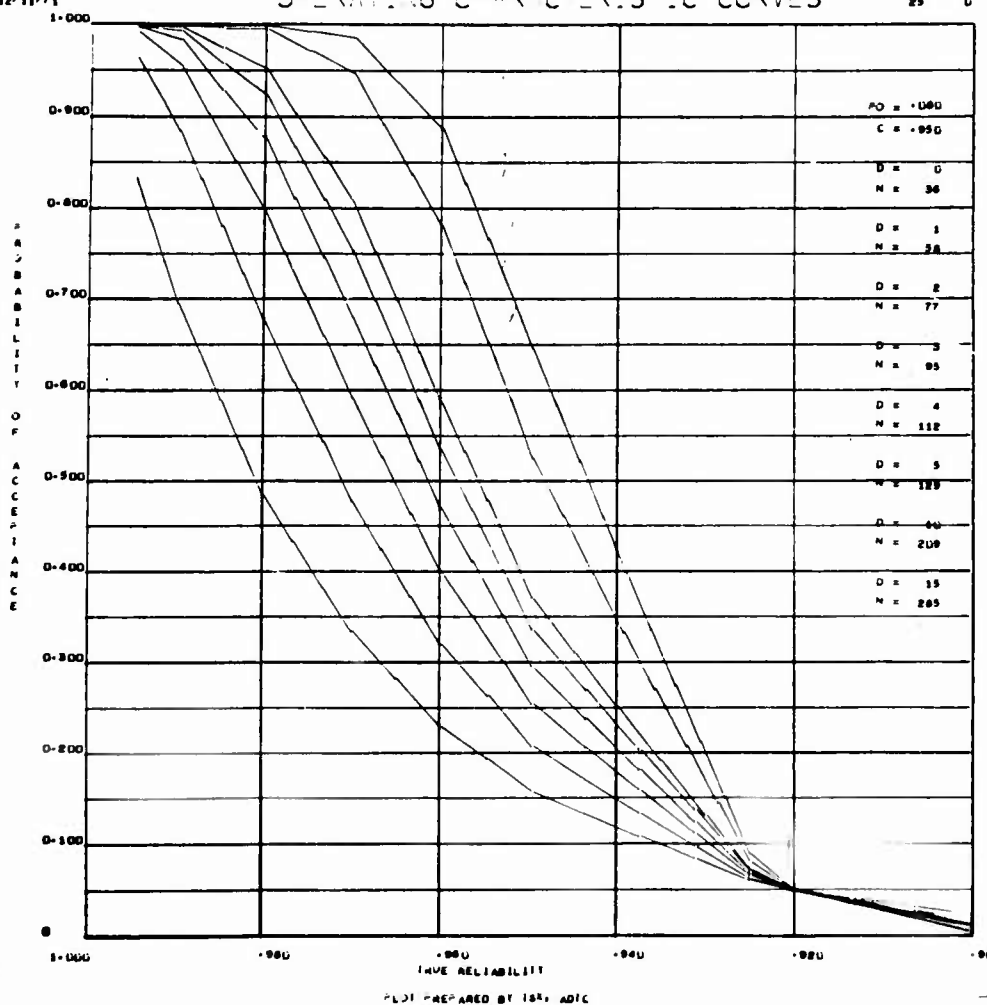
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OPERATING CHARACTERISTIC CURVES

A114

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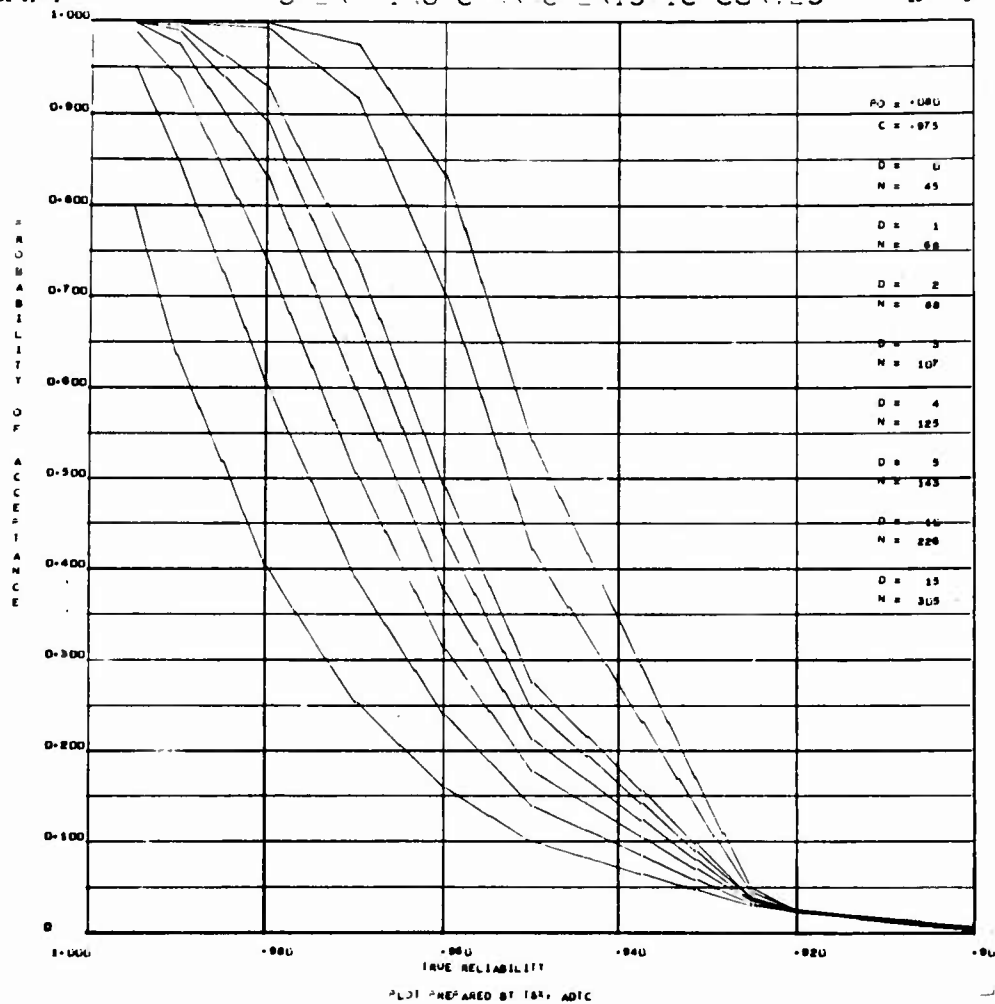


12/11/71

OPERATING CHARACTERISTIC CURVES

A114

26



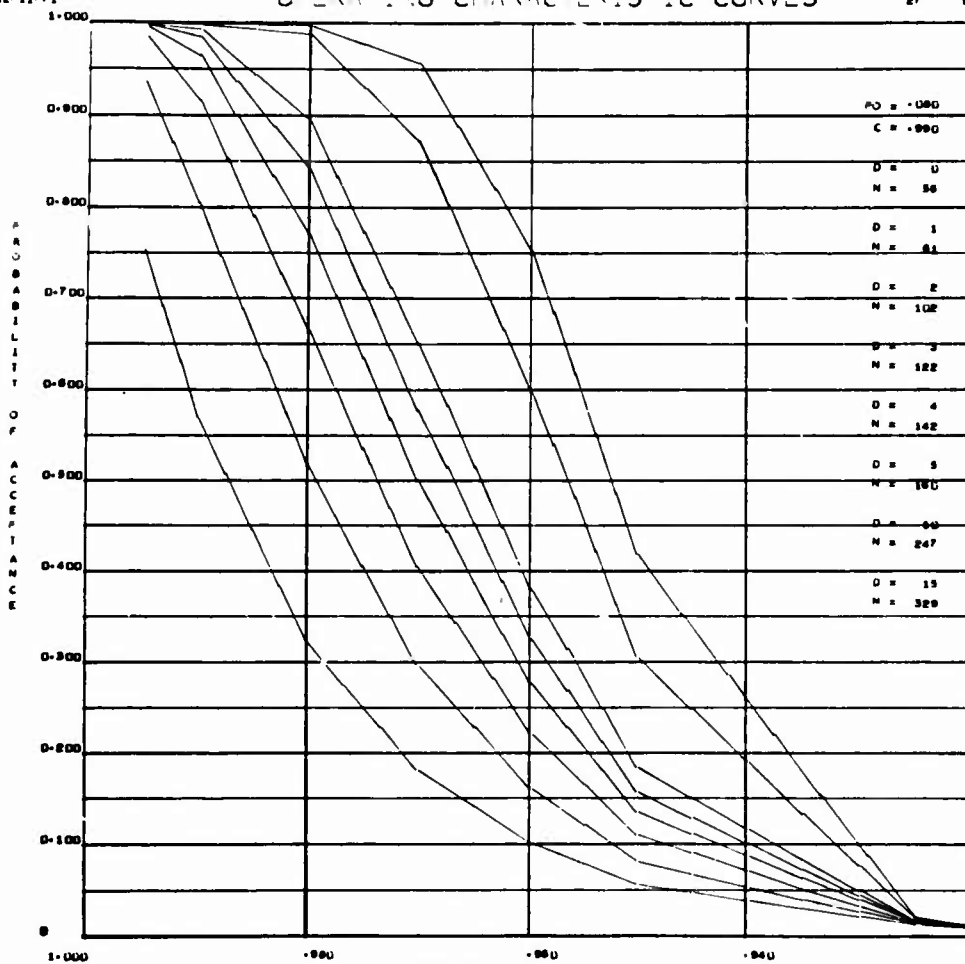
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

27

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PLOT PREPARED BY 10A, ADTC

APPENDIX IX
OPERATING CHARACTERISTIC
CURVES ($p_0 = .090$)

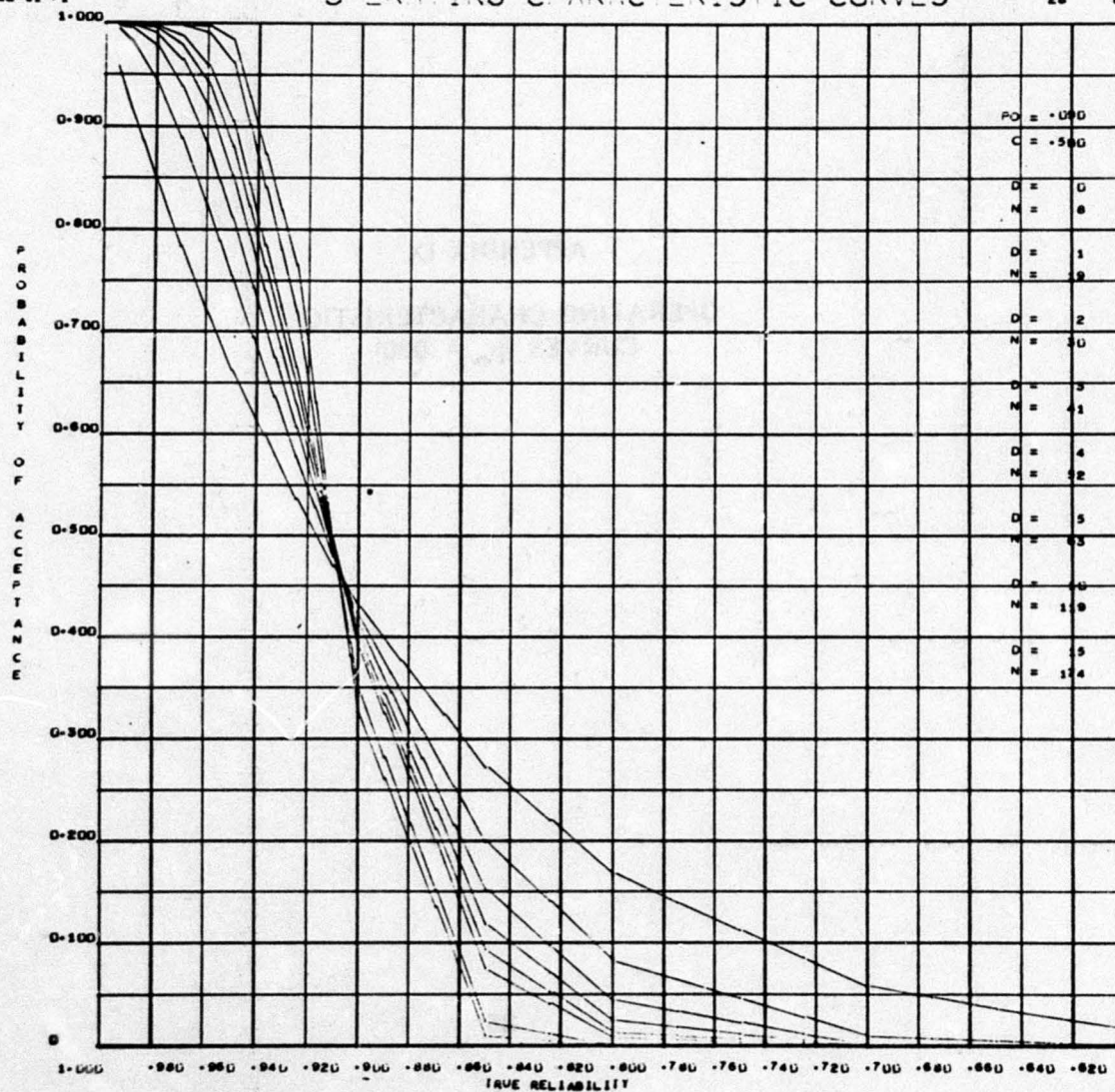
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OPERATING CHARACTERISTIC CURVES

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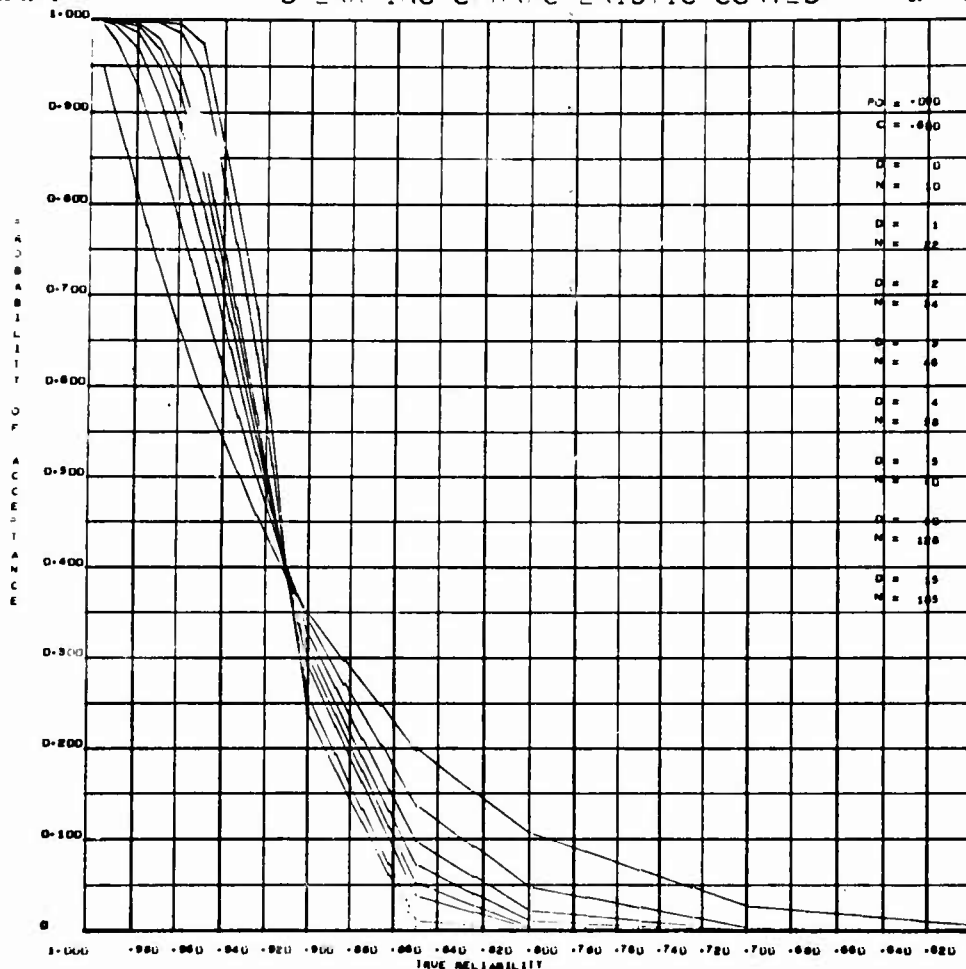


PLOT PREPARED BY ISX-ADIC

12/11/71

OPERATING CHARACTERISTIC CURVES

A114 20 07



PLOT PREPARED BY 181, ADTC

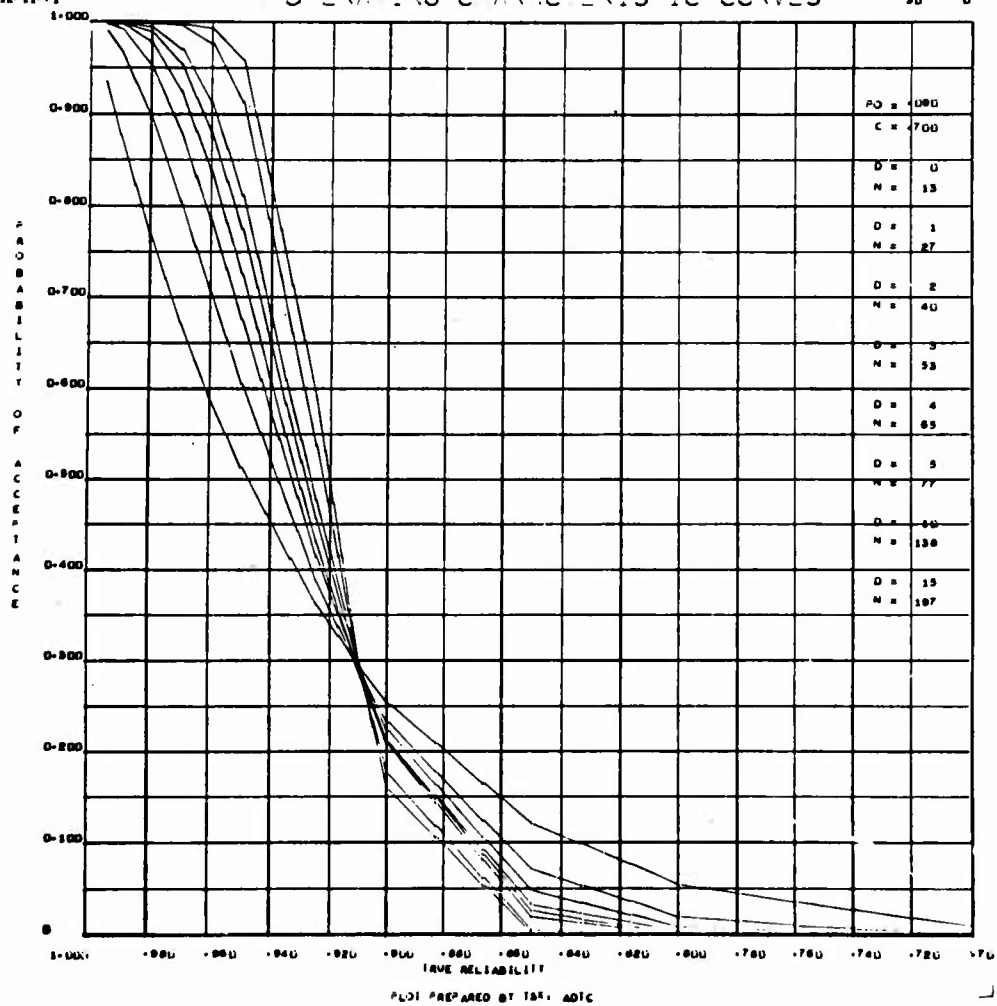
12/11/71

OPERATING CHARACTERISTIC CURVES

A314

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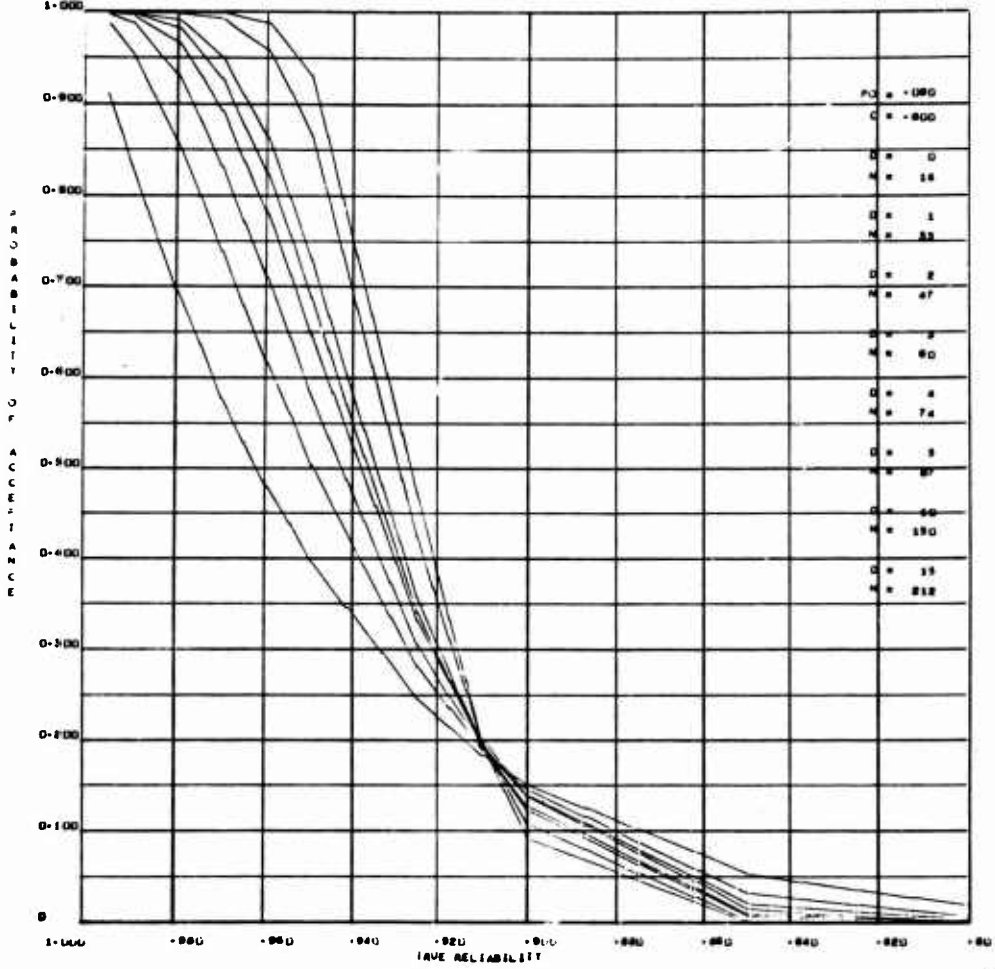
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12/11/71

OPERATING CHARACTERISTIC CURVES

A314 31 07



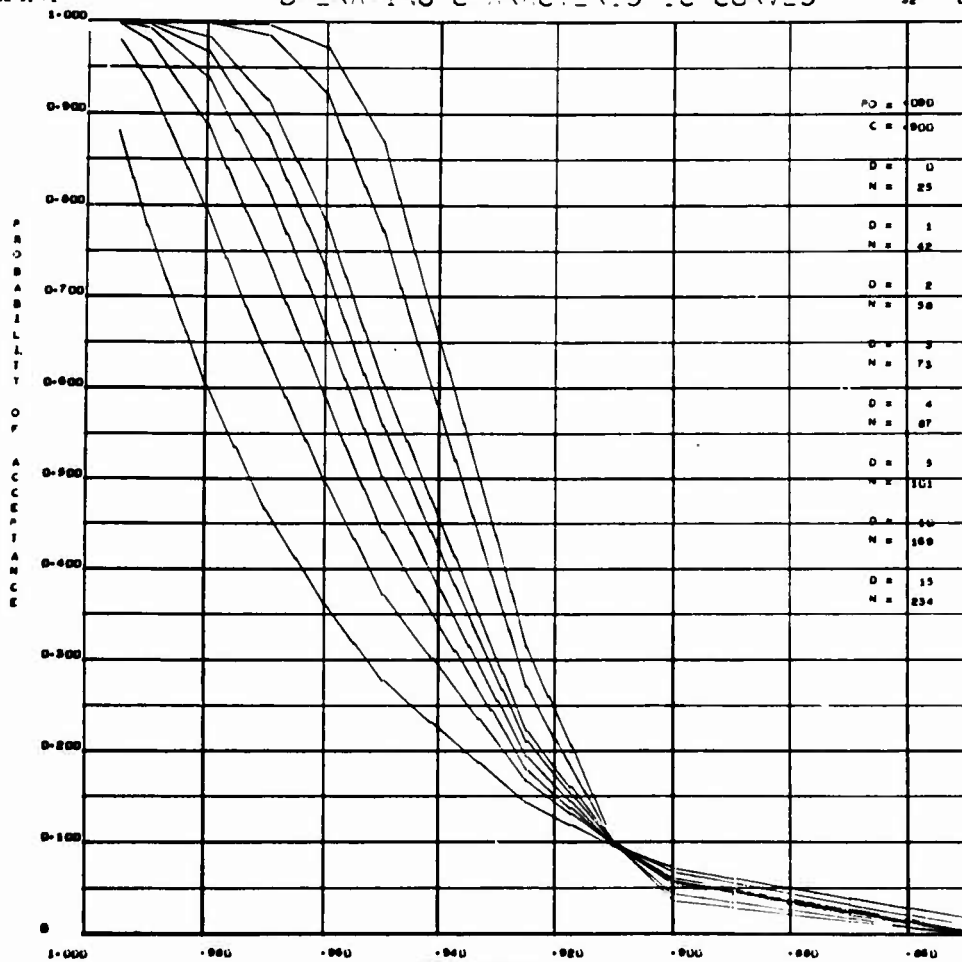
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

32

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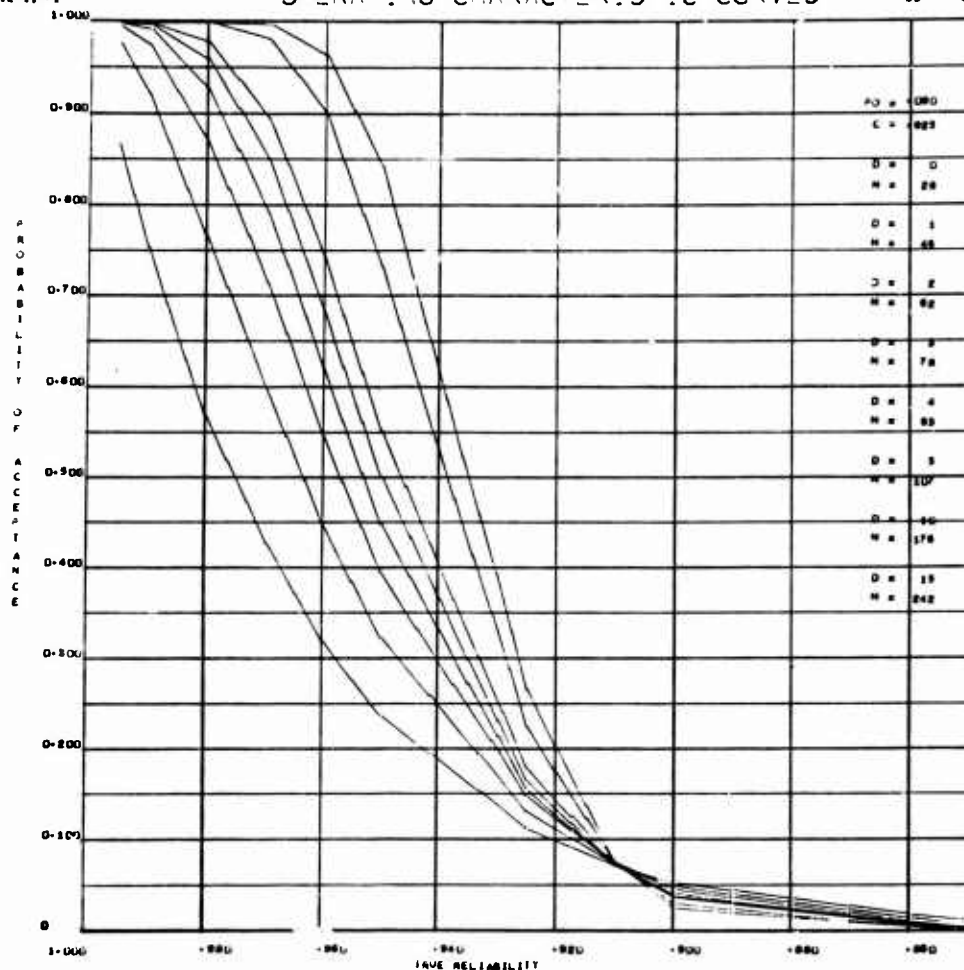


PLOT PREPARED BY 184, ADIC

12/15/73

OPERATING CHARACTERISTIC CURVES

A114 33 0



PLOT PREPARED BY TAY, ADIC

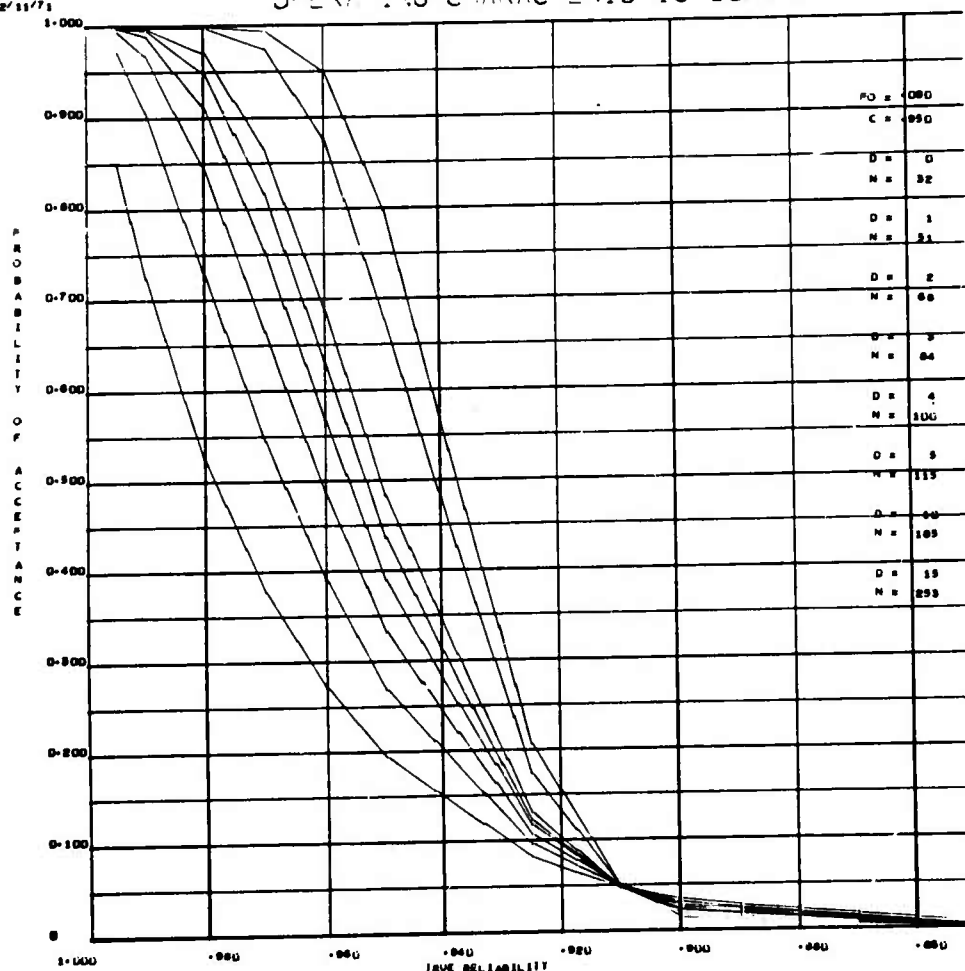
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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PLOT PREPARED BY 154 ADTC

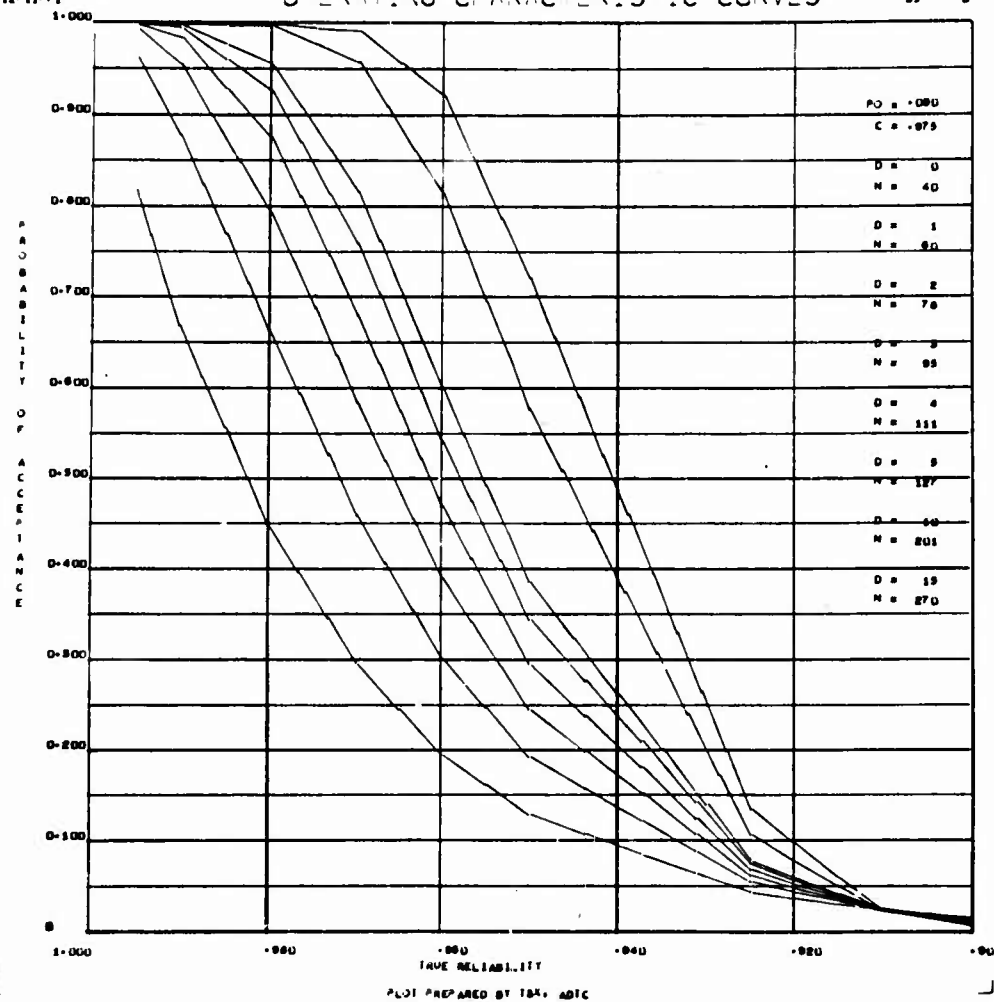
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OPERATING CHARACTERISTIC CURVES

A114

39

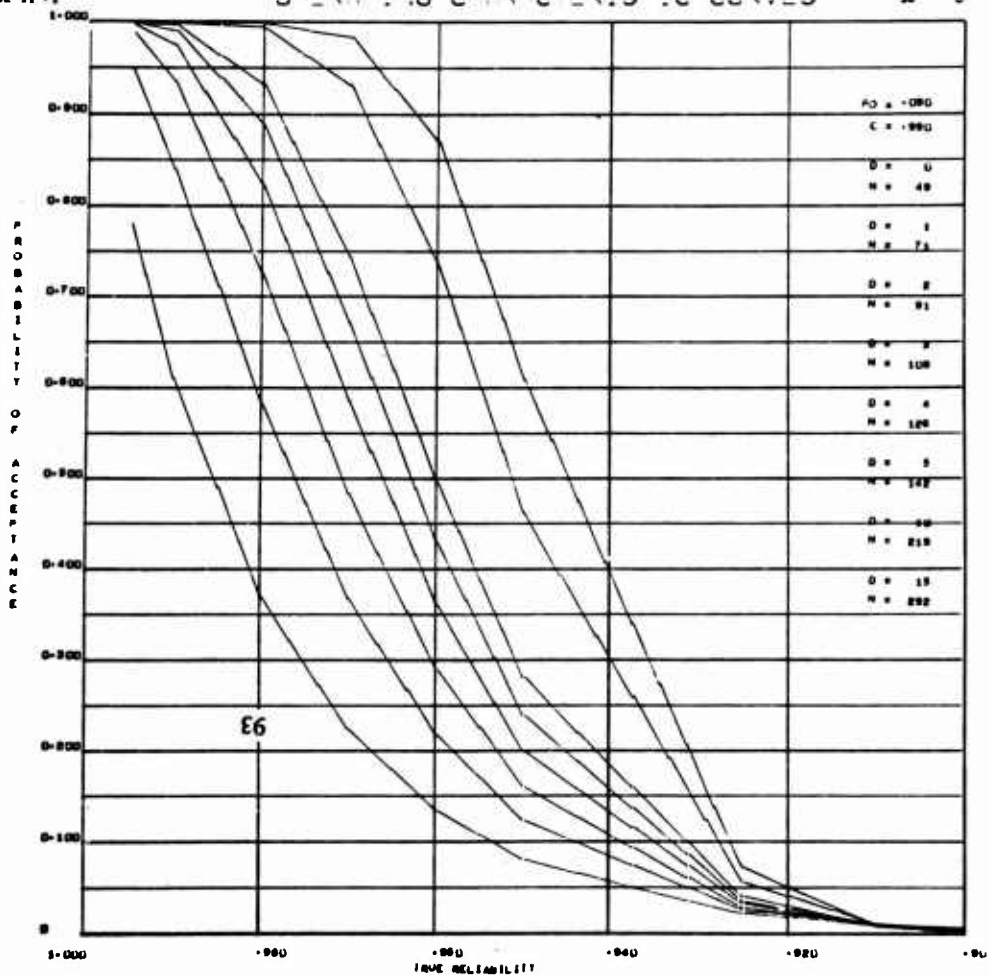
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12/11/73

OPERATING CHARACTERISTIC CURVES

A114 36 07



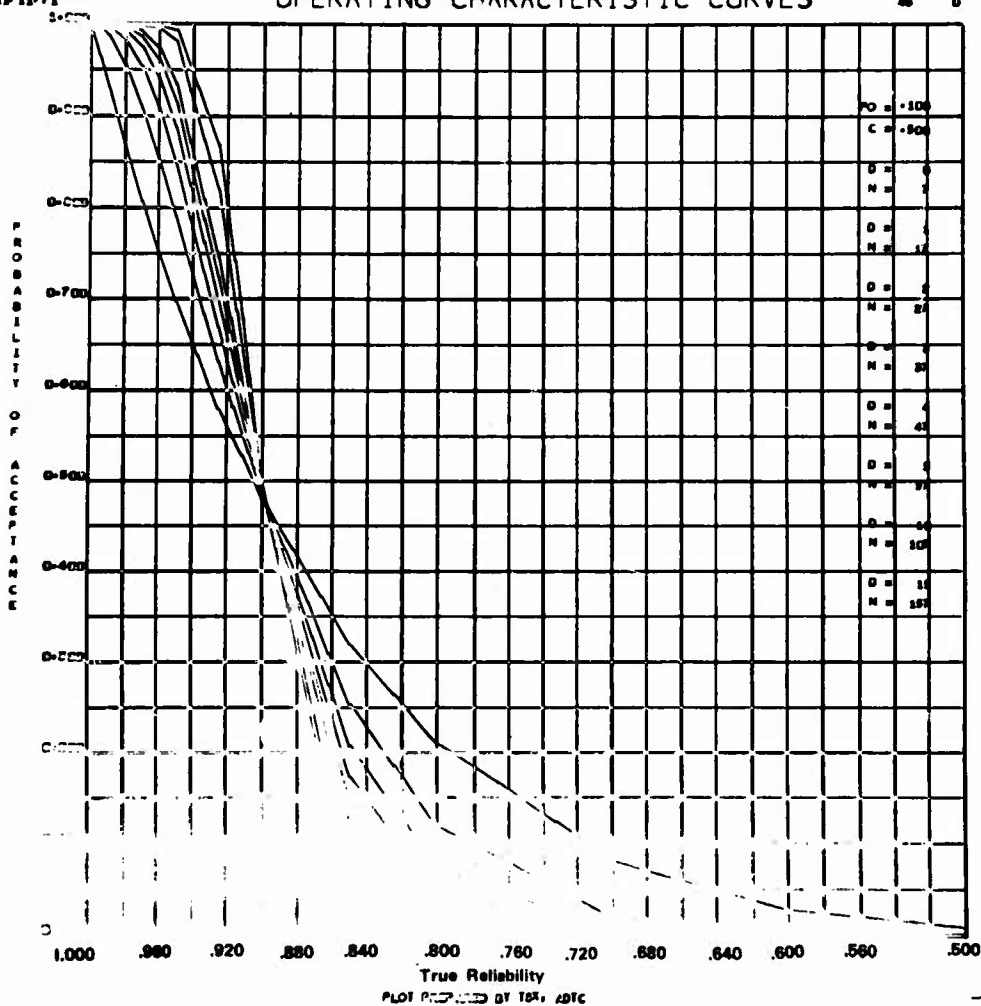
PLOT PREPARED BY T&A, ADIC

APPENDIX X
OPERATING CHARACTERISTIC
CURVES ($p_0 = .100$)

12/13/73

OPERATING CHARACTERISTIC CURVES

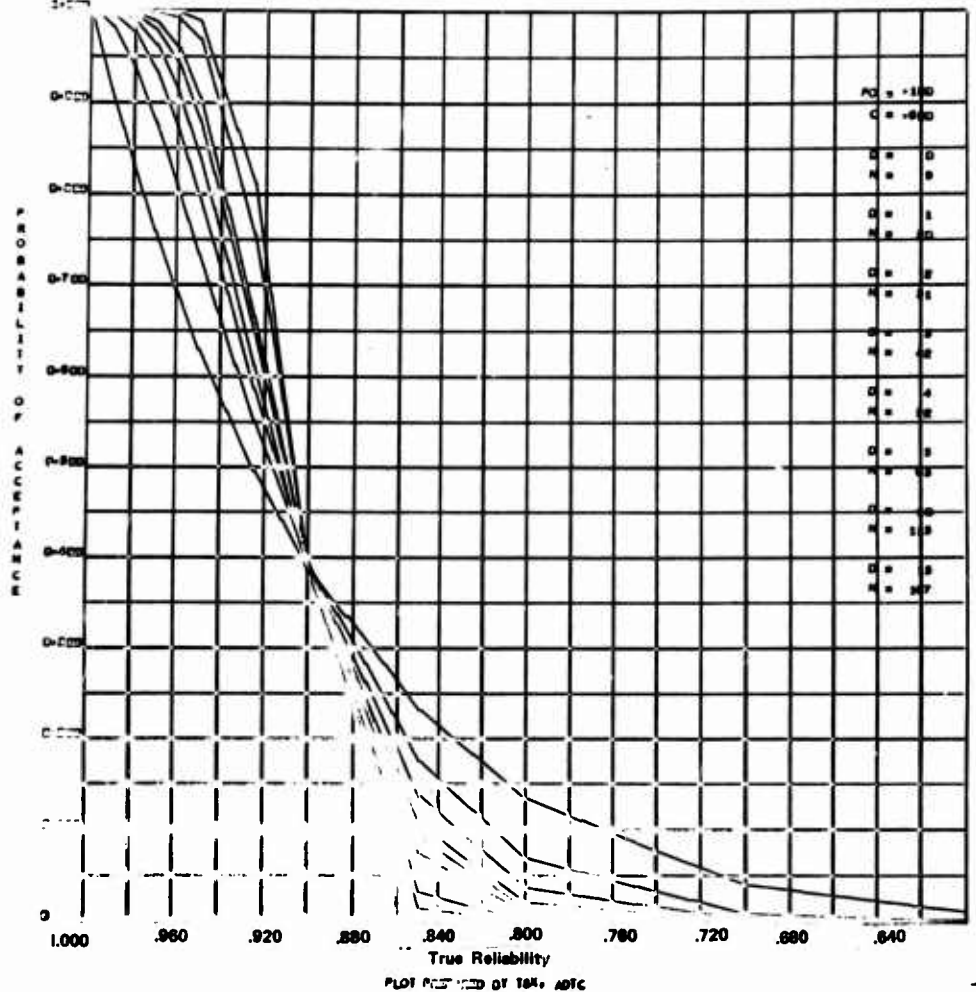
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10/11/71

OPERATING CHARACTERISTIC CURVES

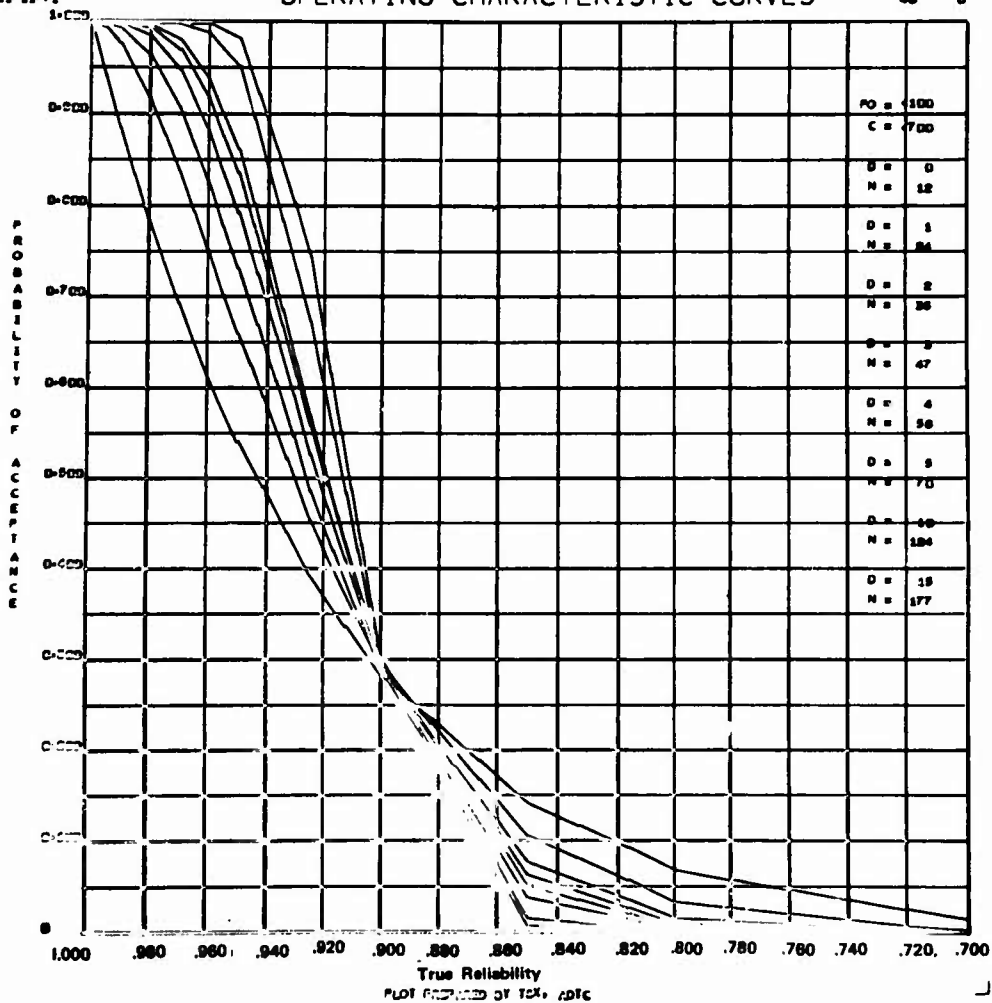
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14-11-71

OPERATING CHARACTERISTIC CURVES

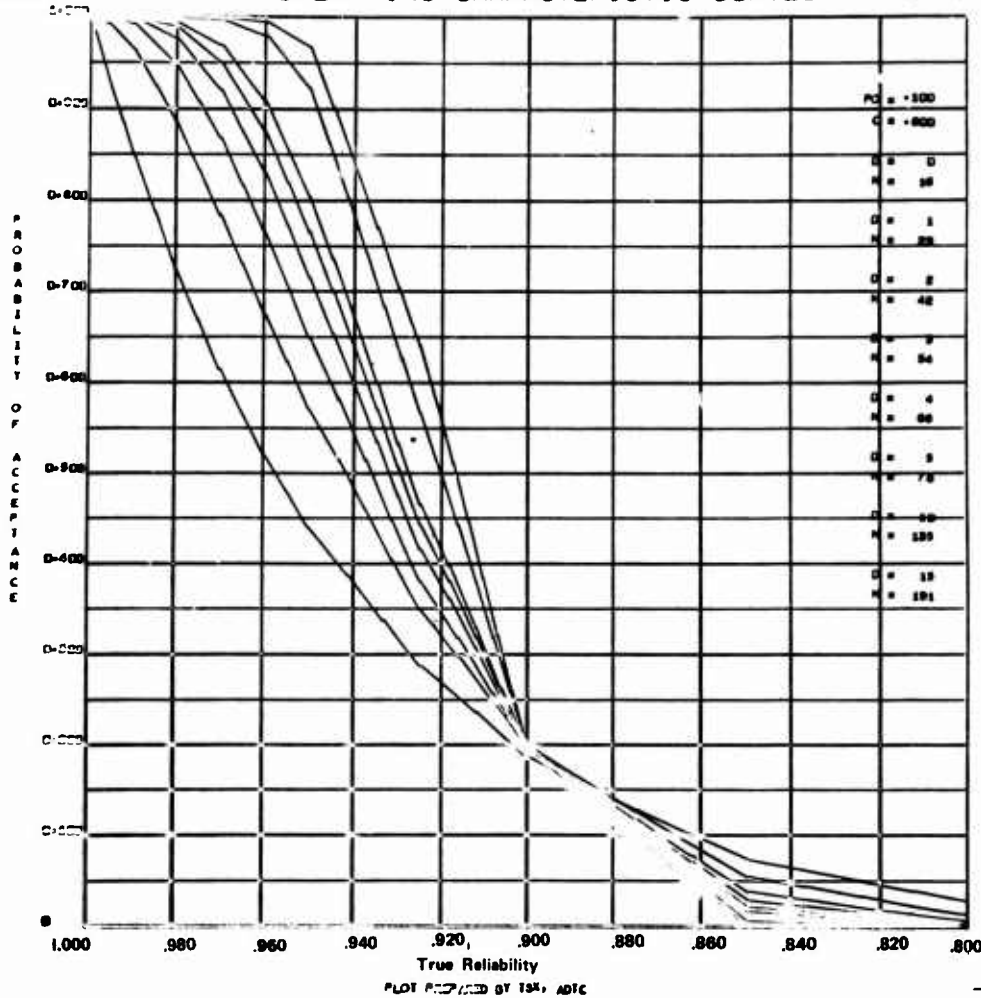
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10/11/71

OPERATING CHARACTERISTIC CURVES

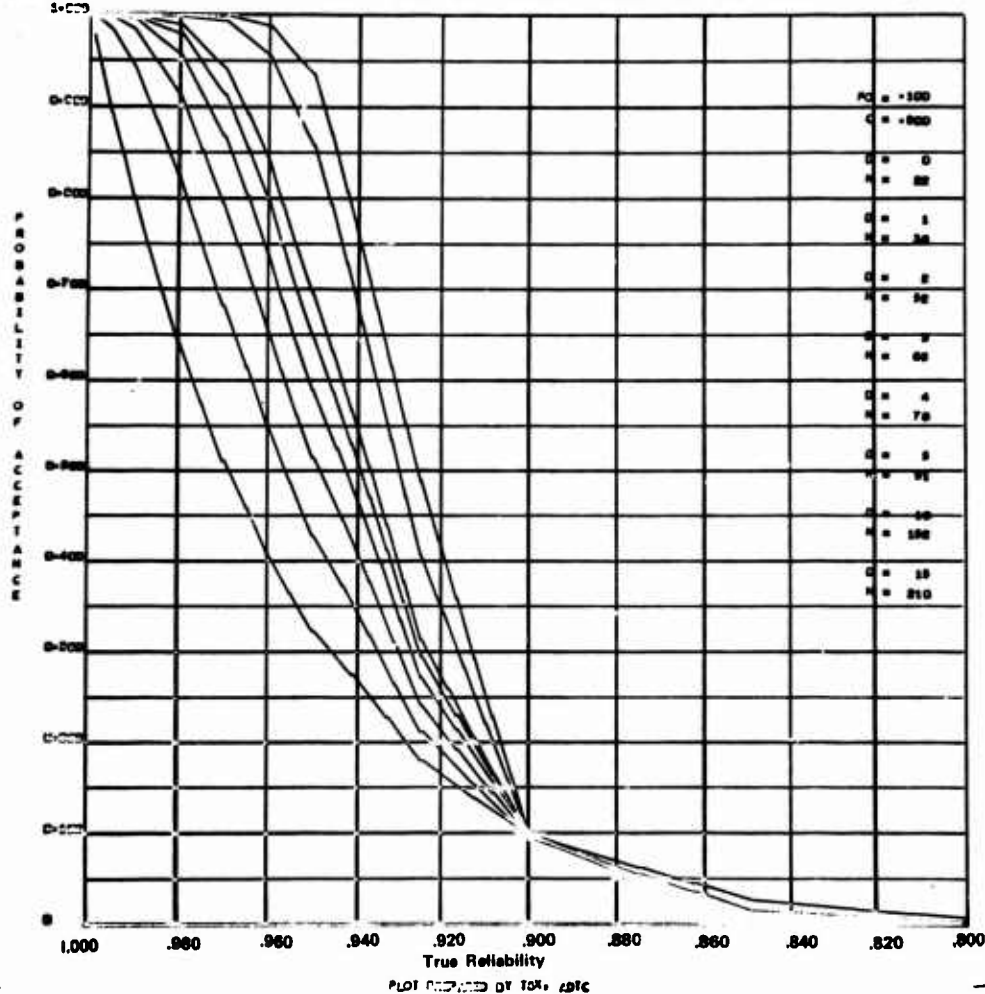
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10/11/71

OPERATING CHARACTERISTIC CURVES

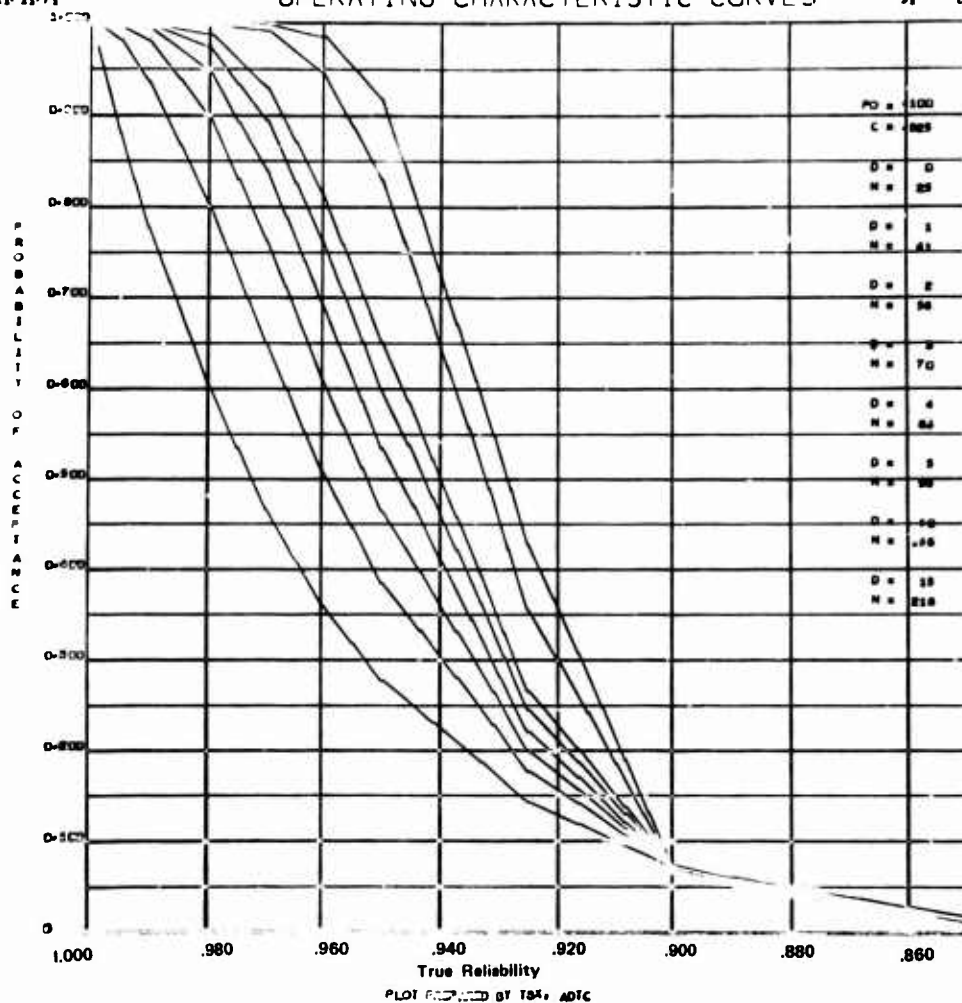
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11/11/71

OPERATING CHARACTERISTIC CURVES

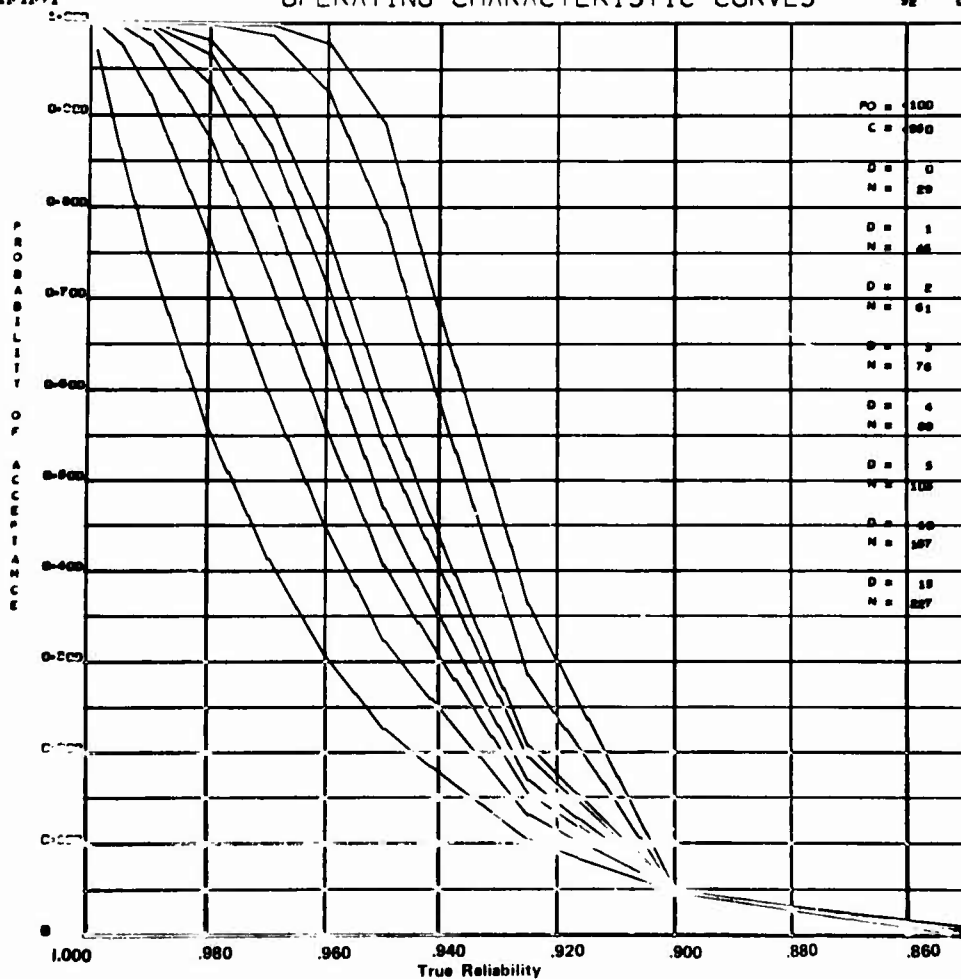
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12/11/71

OPERATING CHARACTERISTIC CURVES

A10E 92 0

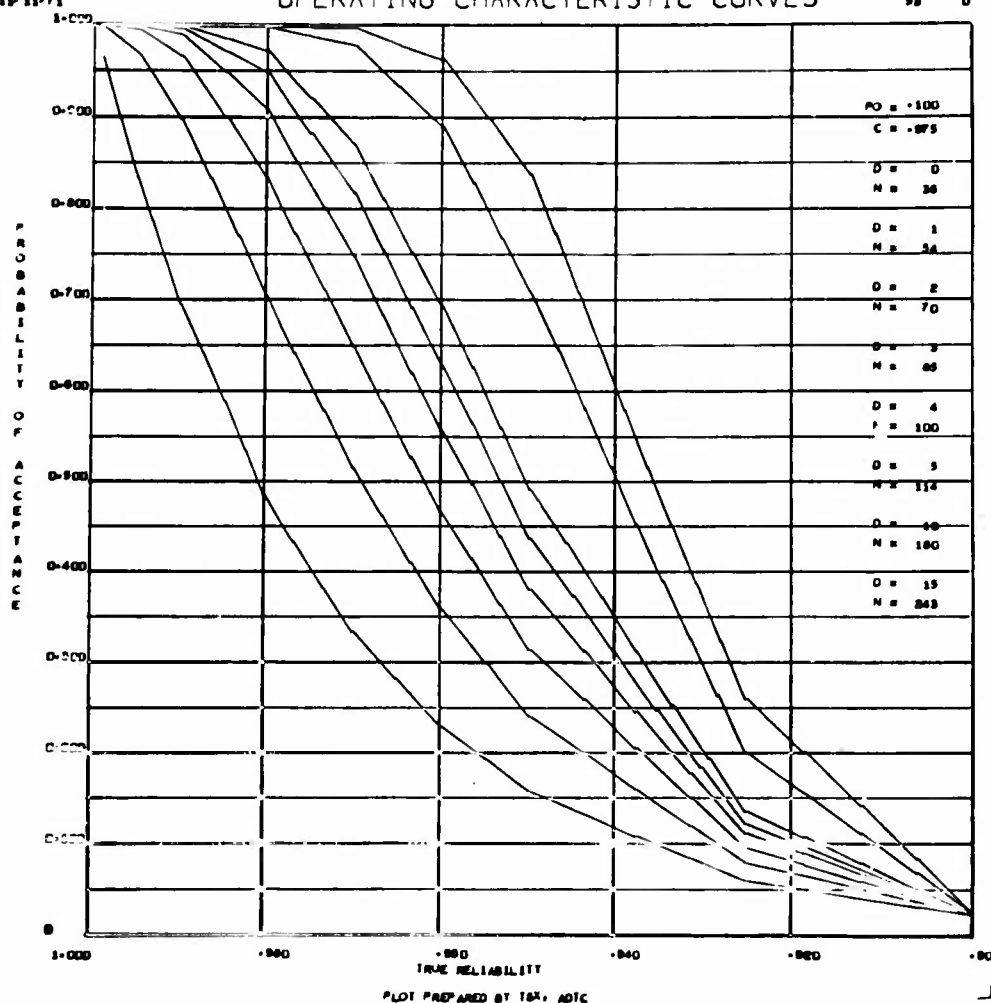


PLOT PREPARED BY 184. ADTC

12/11/71

OPERATING CHARACTERISTIC CURVES

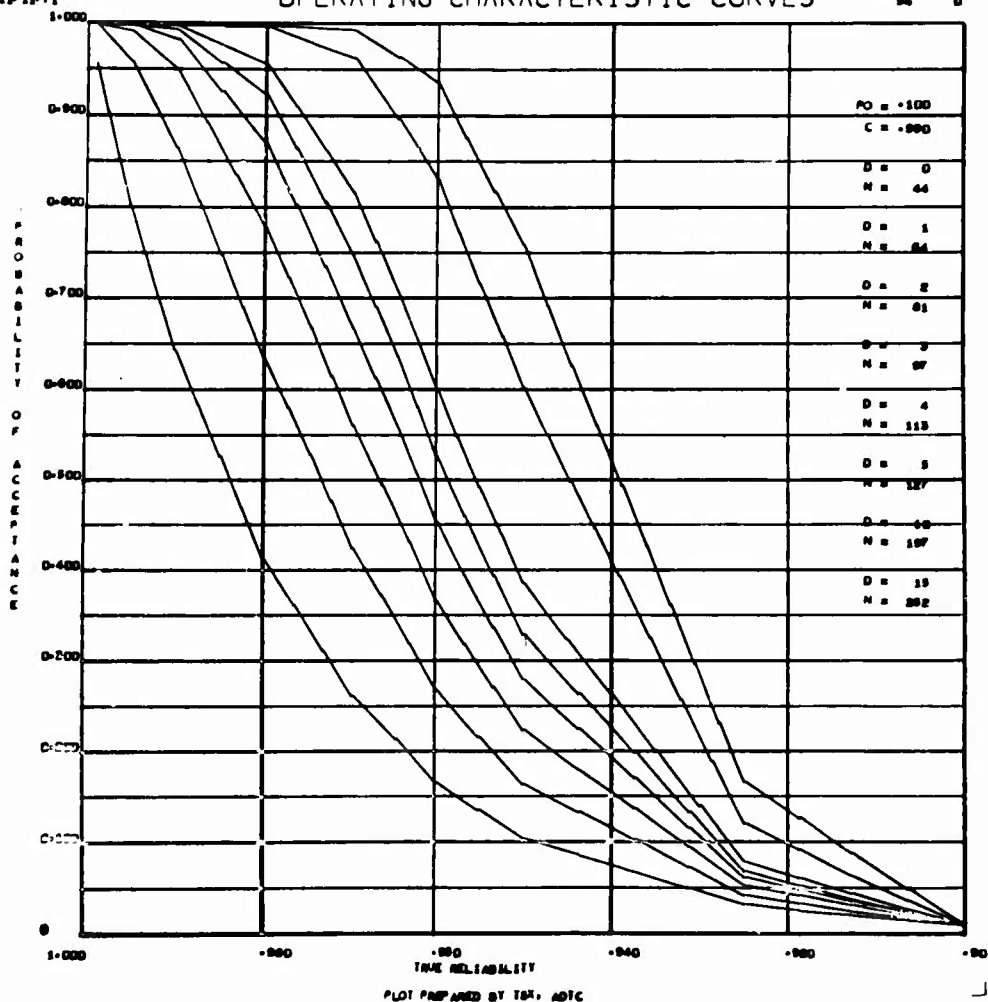
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14-1171

OPERATING CHARACTERISTIC CURVES

ASCE 84 8

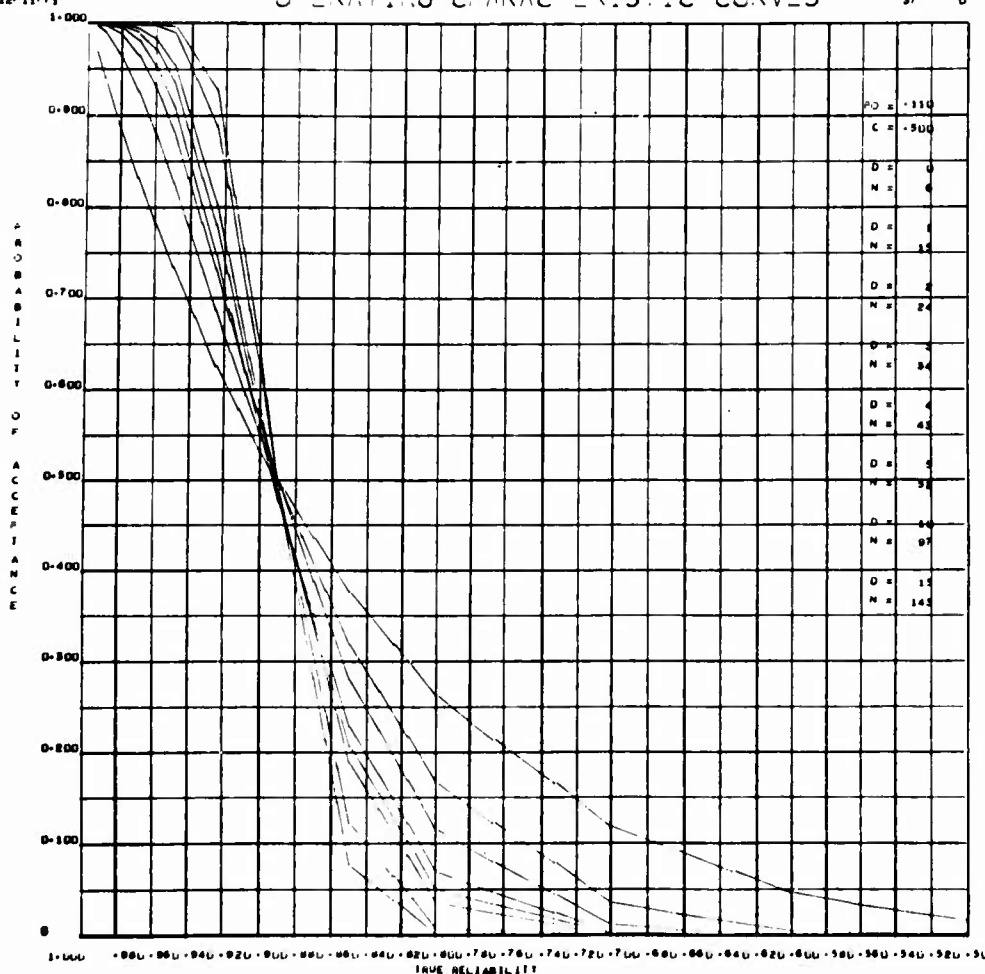


APPENDIX XI
OPERATING CHARACTERISTIC
CURVES ($p_0 = .110$)

12/11/71

OPERATING CHARACTERISTIC CURVES

A114
37



PLT PREPARED BY 154, ADTC

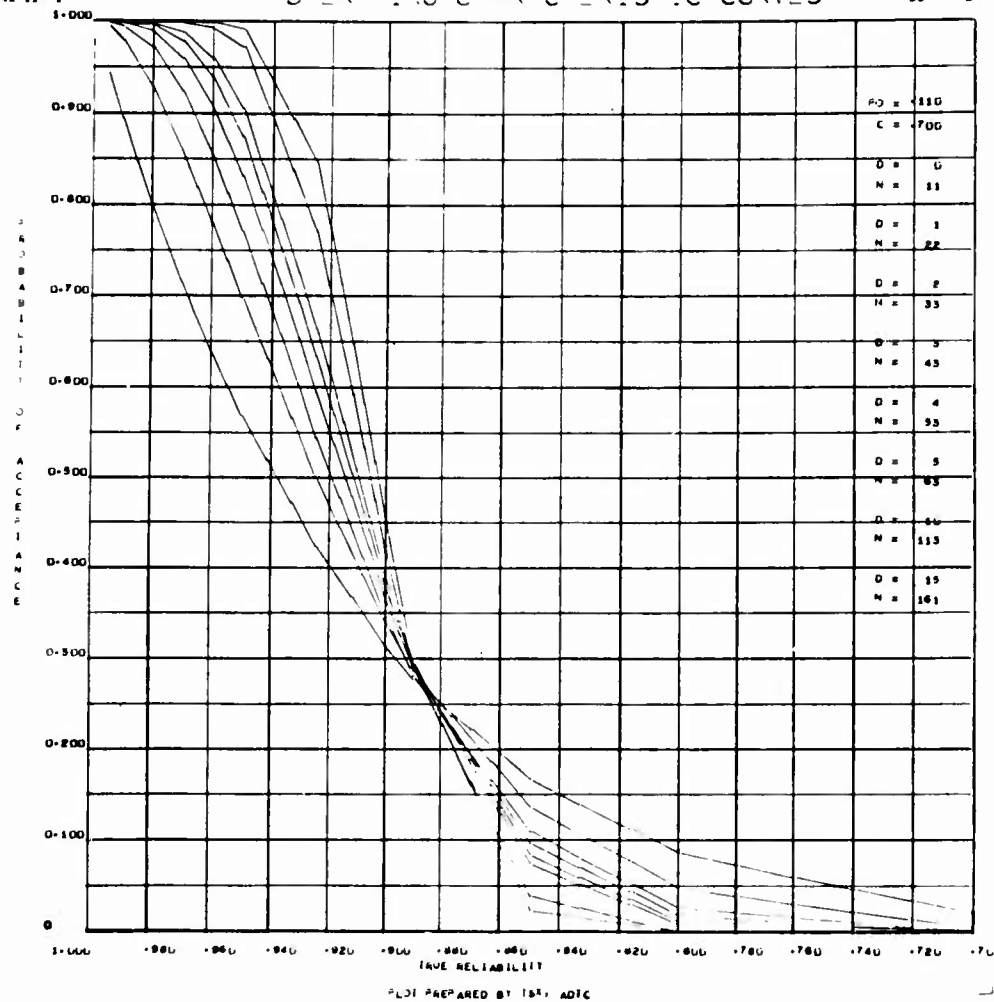
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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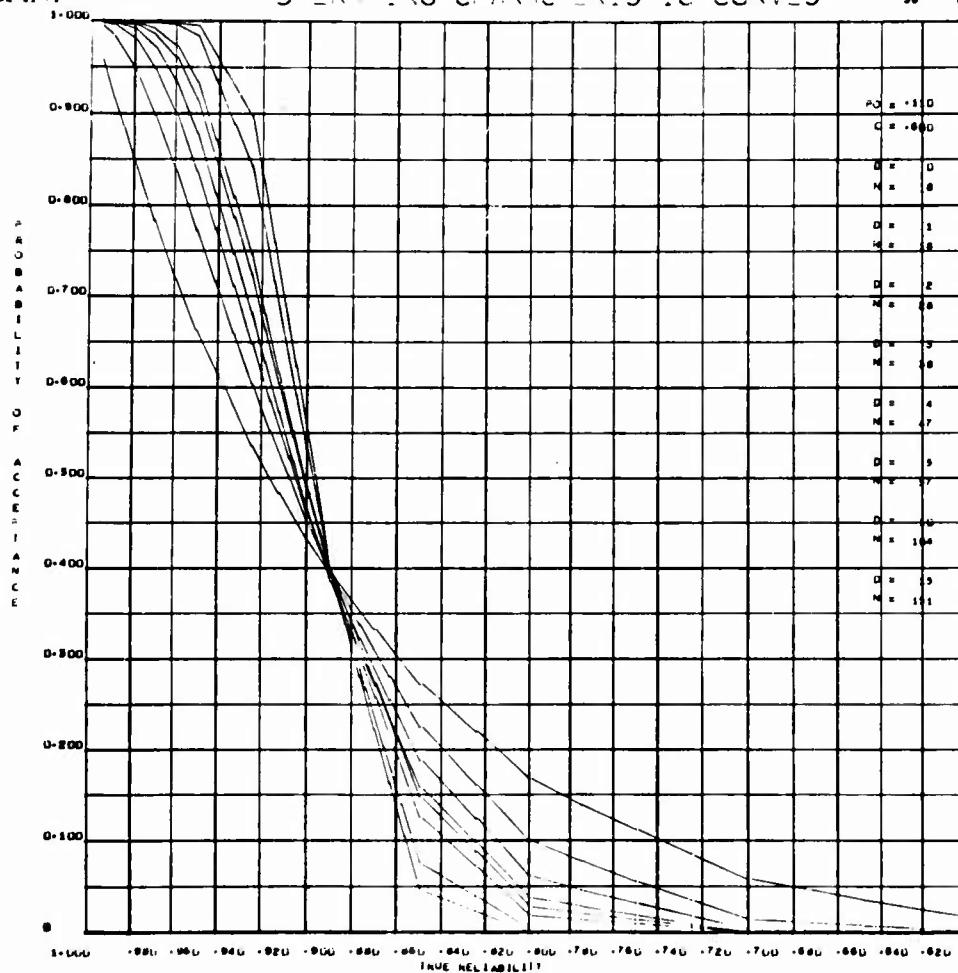
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

38

07



PLT PREPARED BY 1341 ADIC

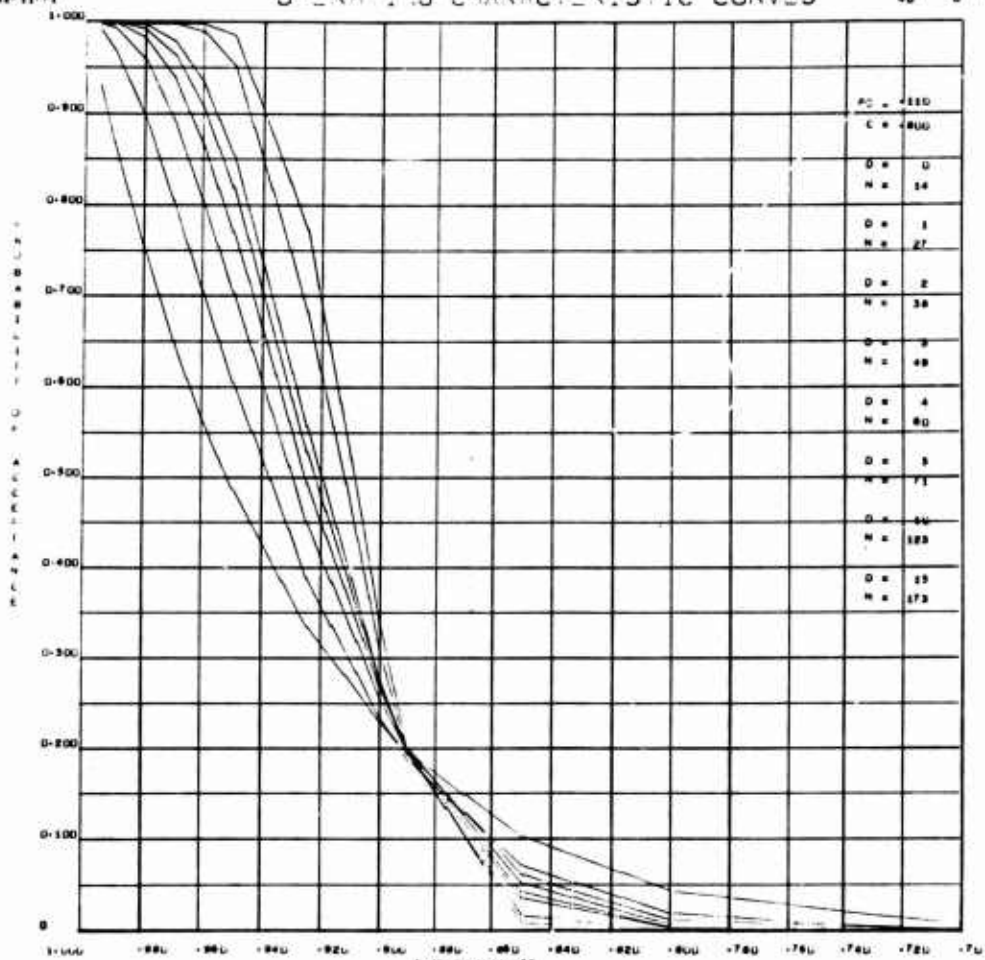
12/11/73

OPERATING CHARACTERISTIC CURVES

4134

40

07



PLOT PREPARED BY 131-ADTC

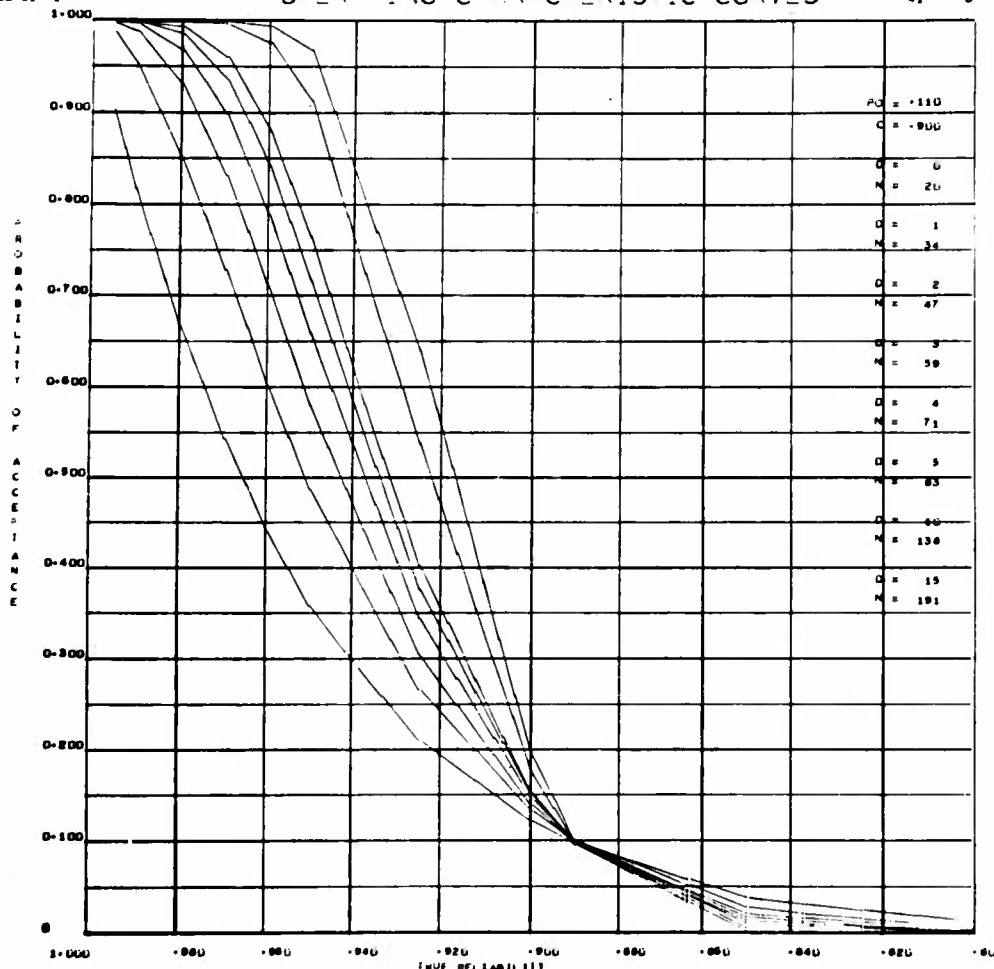
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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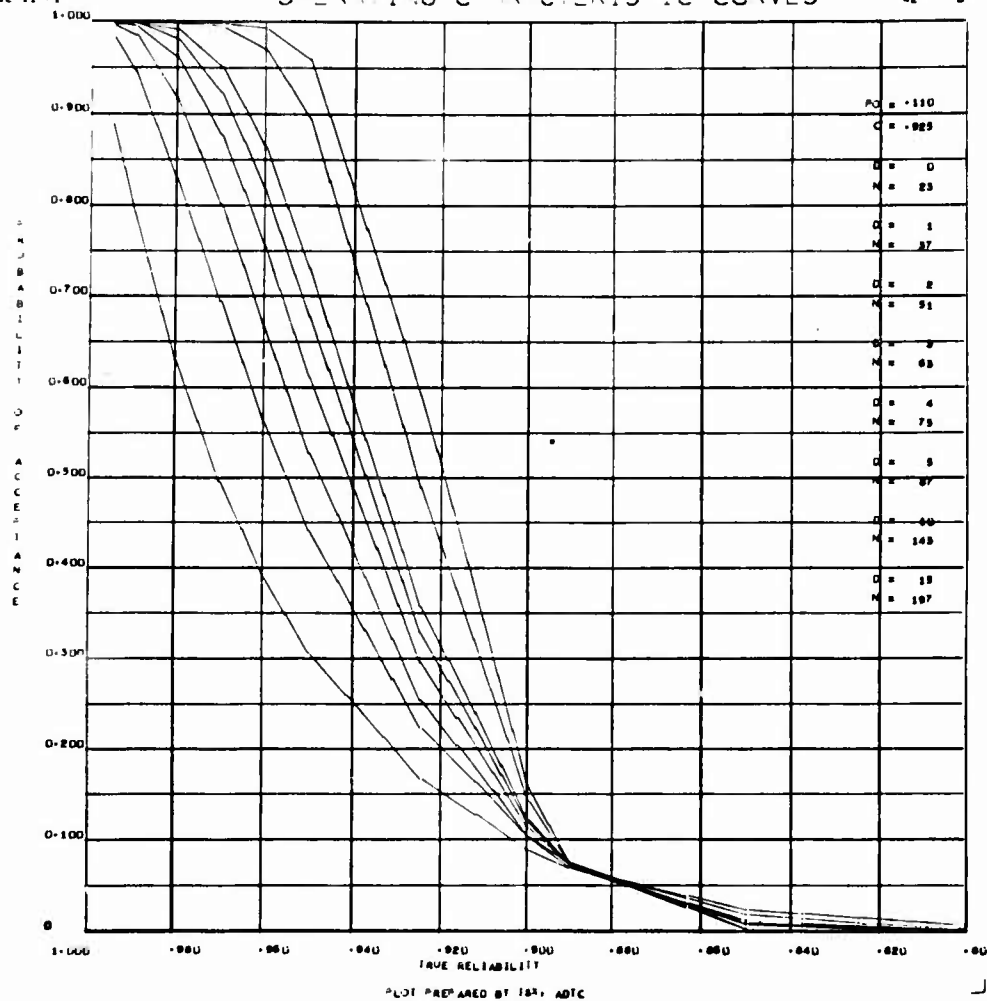
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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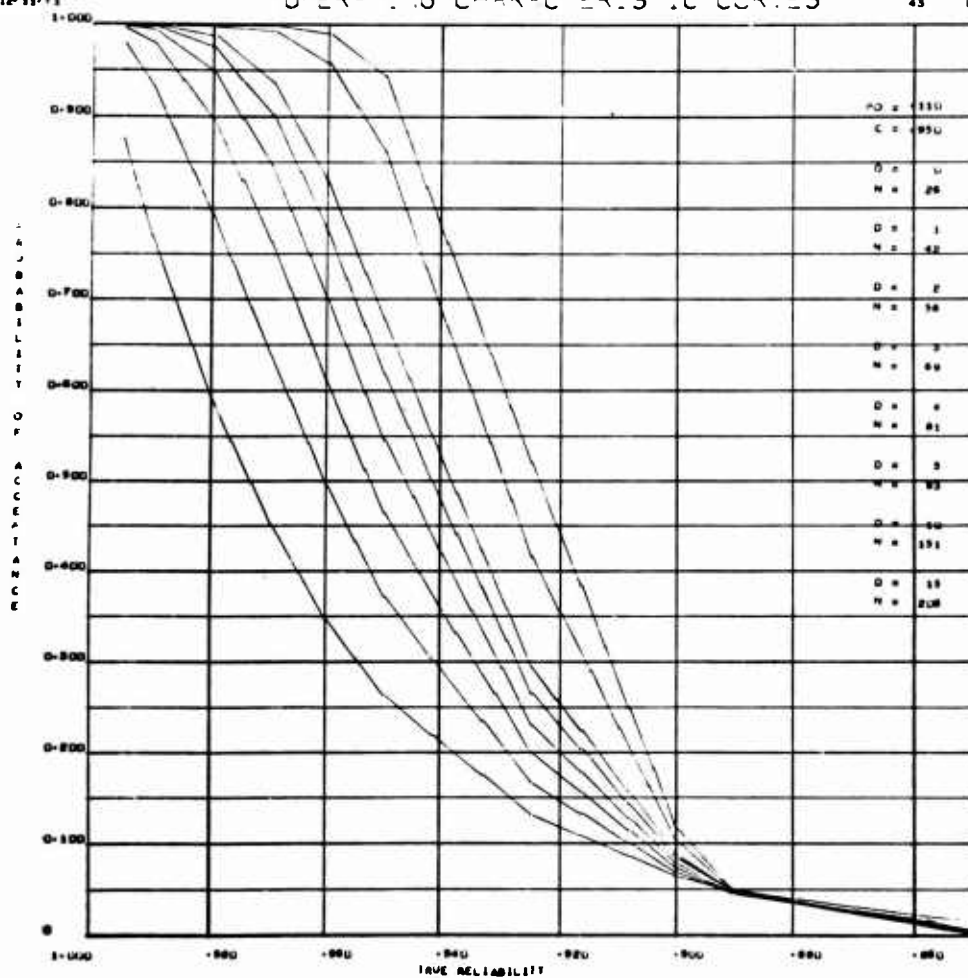
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

43

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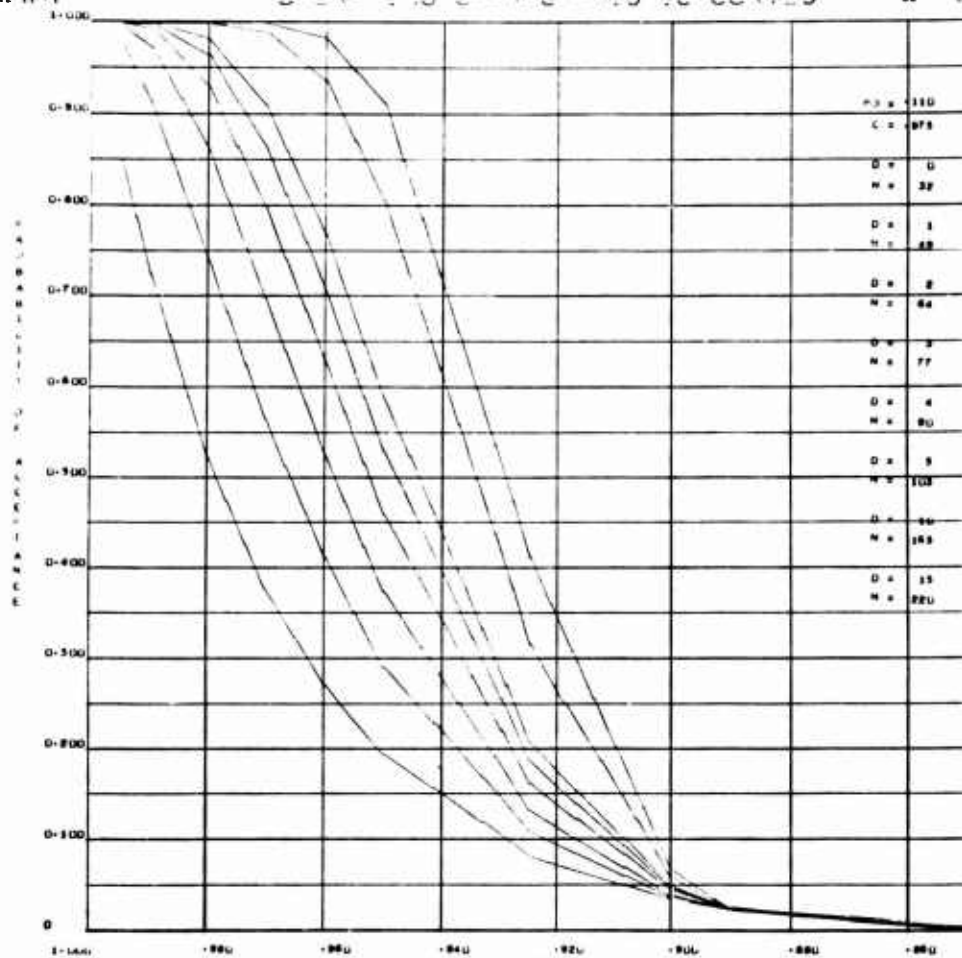


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12/11/71

OPERATING CHARACTERISTIC CURVES

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-LJ1 - PREPARED BY 154 ADIC

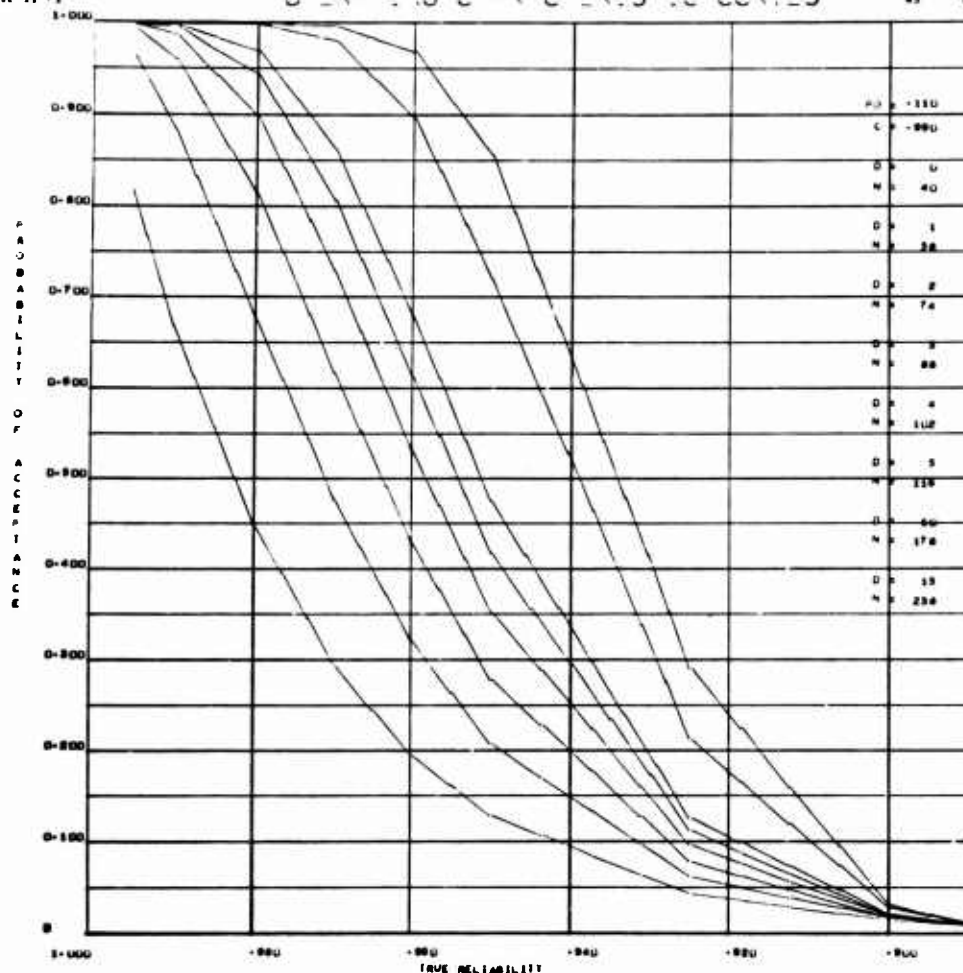
12/11/73

OPERATING CHARACTERISTIC CURVES

4114

43

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PLOT PREPARED BY 181. ADTC

APPENDIX XII

OPERATING CHARACTERISTIC
CURVES ($p_0 = .120$)

A314



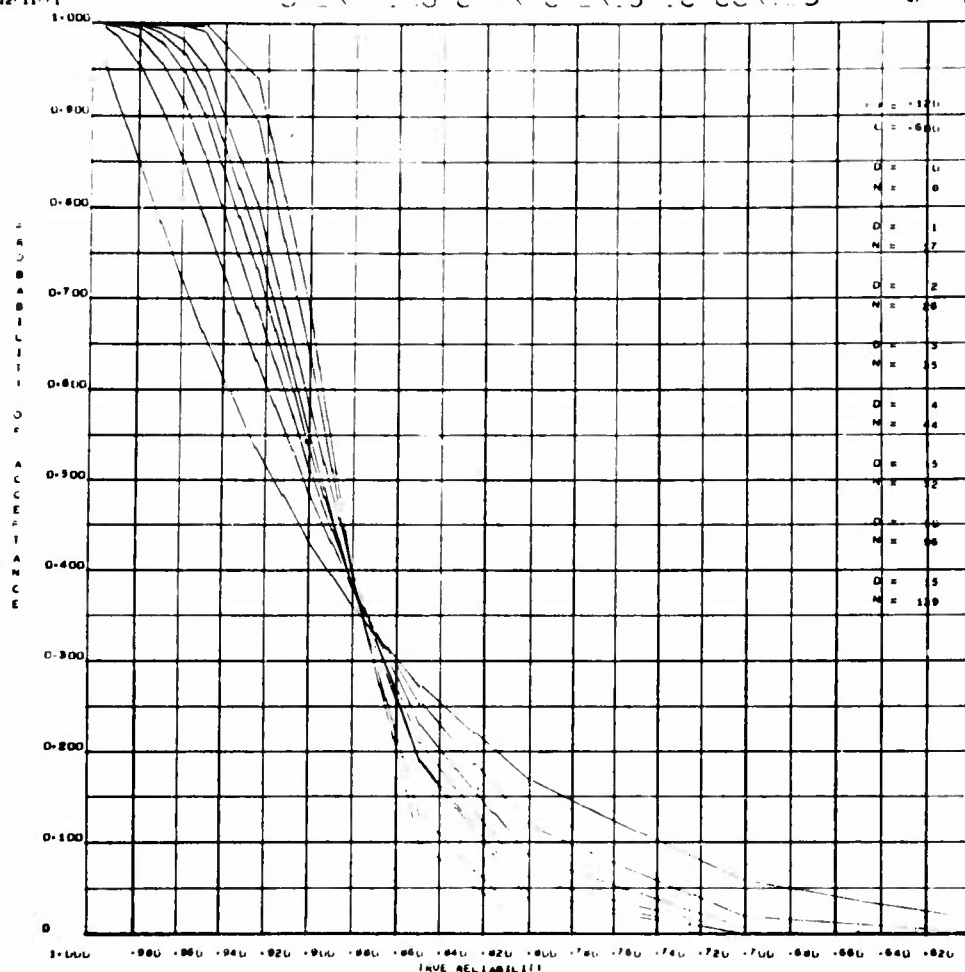
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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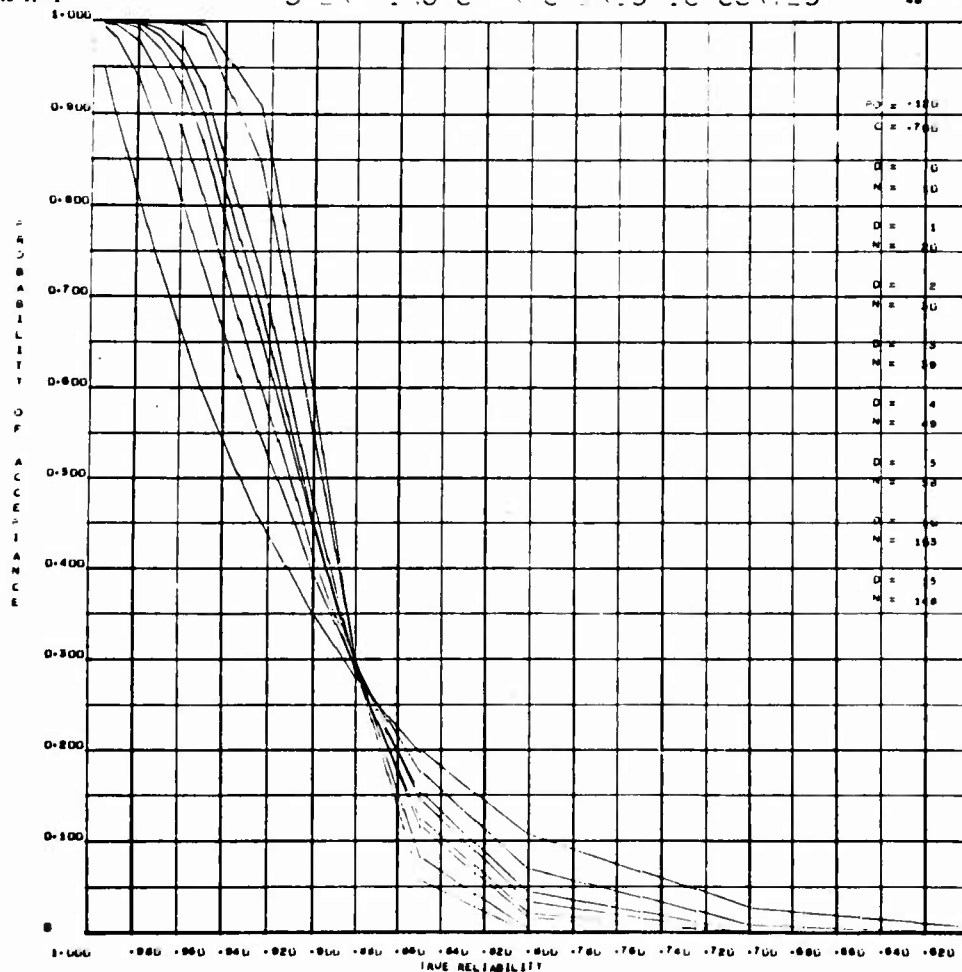
PLOT PREPARED BY TAA: ADIC

12/11/71

OPERATING CHARACTERISTIC CURVES

A114

48



PLOT PREPARED BY T&A ADIC

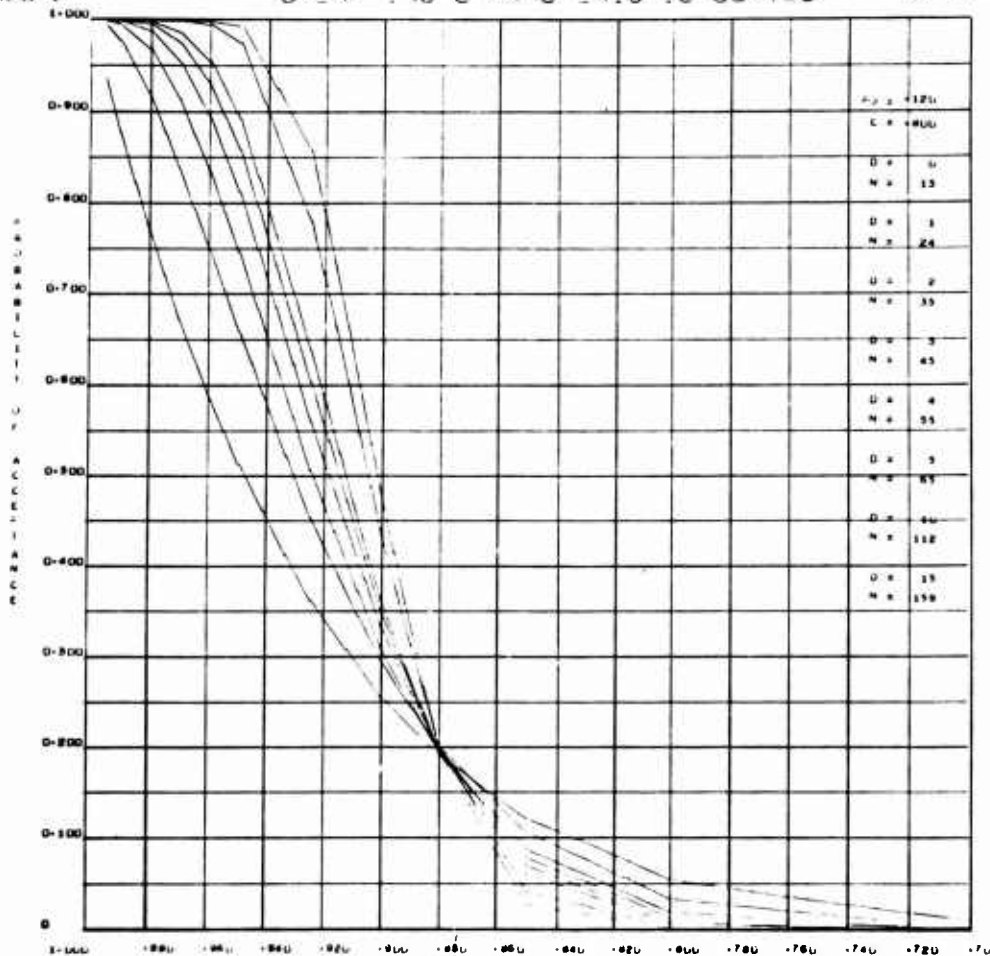
12-31-73

OPERATING CHARACTERISTIC CURVES

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PREPARED BY 154 ADIC

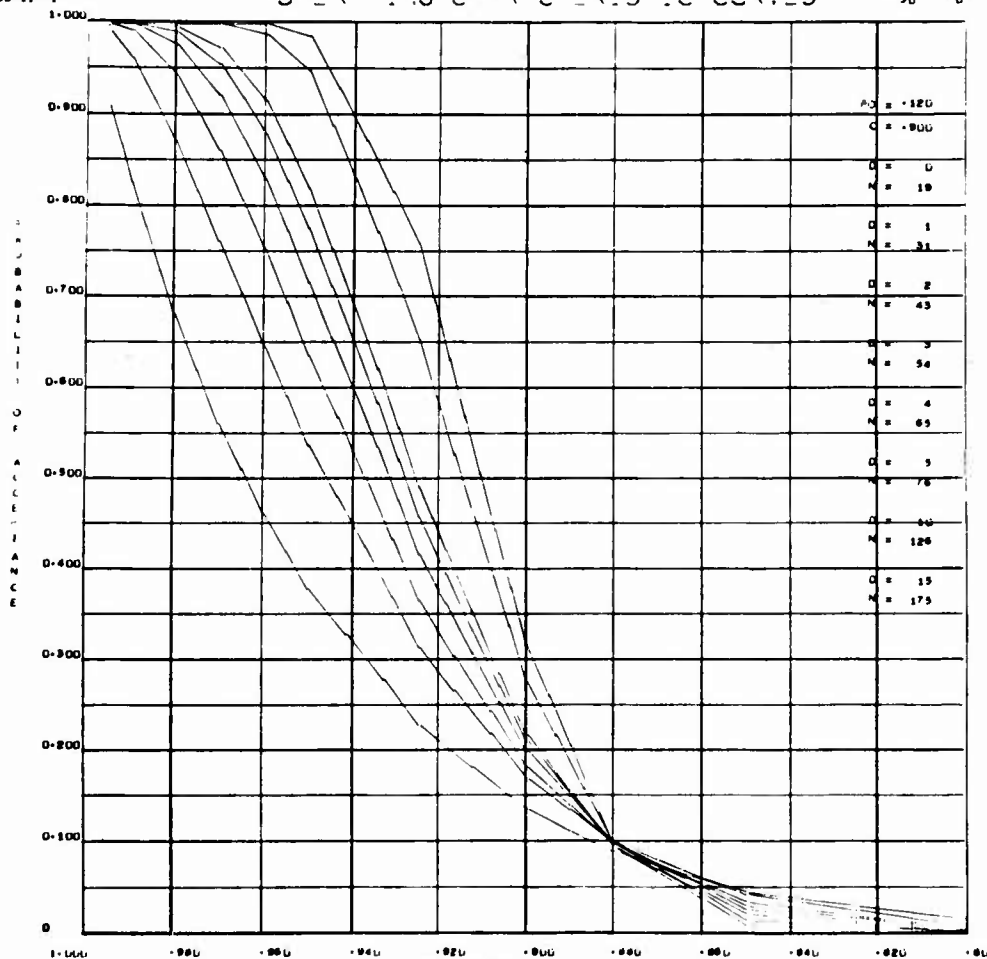
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OPERATING CHARACTERISTIC CURVES

A314

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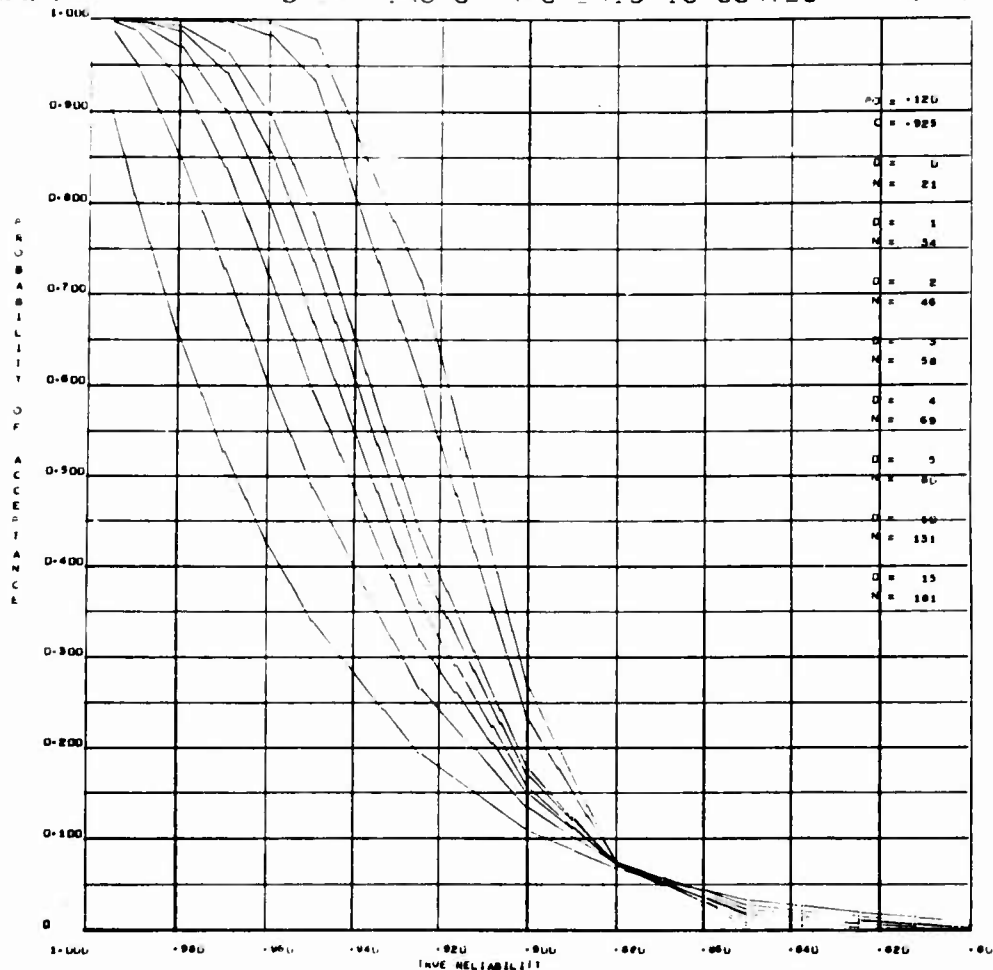
12/11/71

OPERATING CHARACTERISTIC CURVES

A314

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PLOT PREPARED BY 13A, AOTC

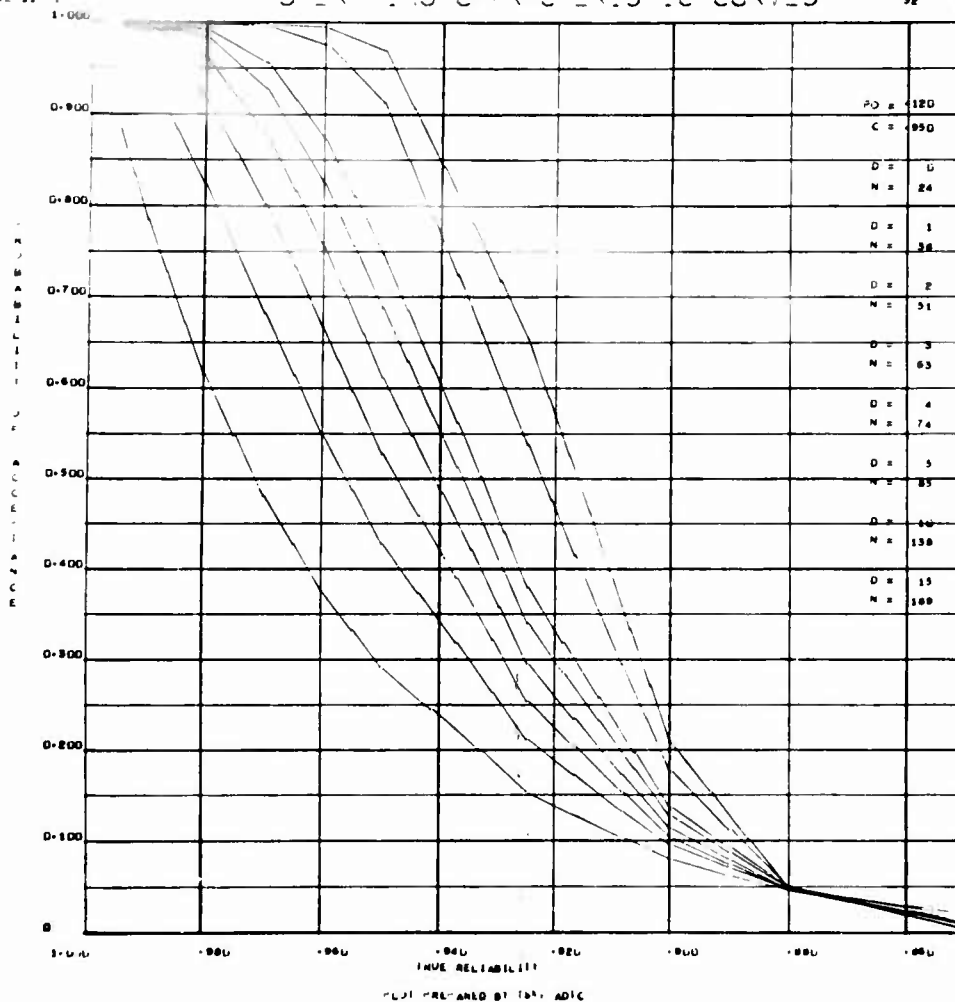
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

92

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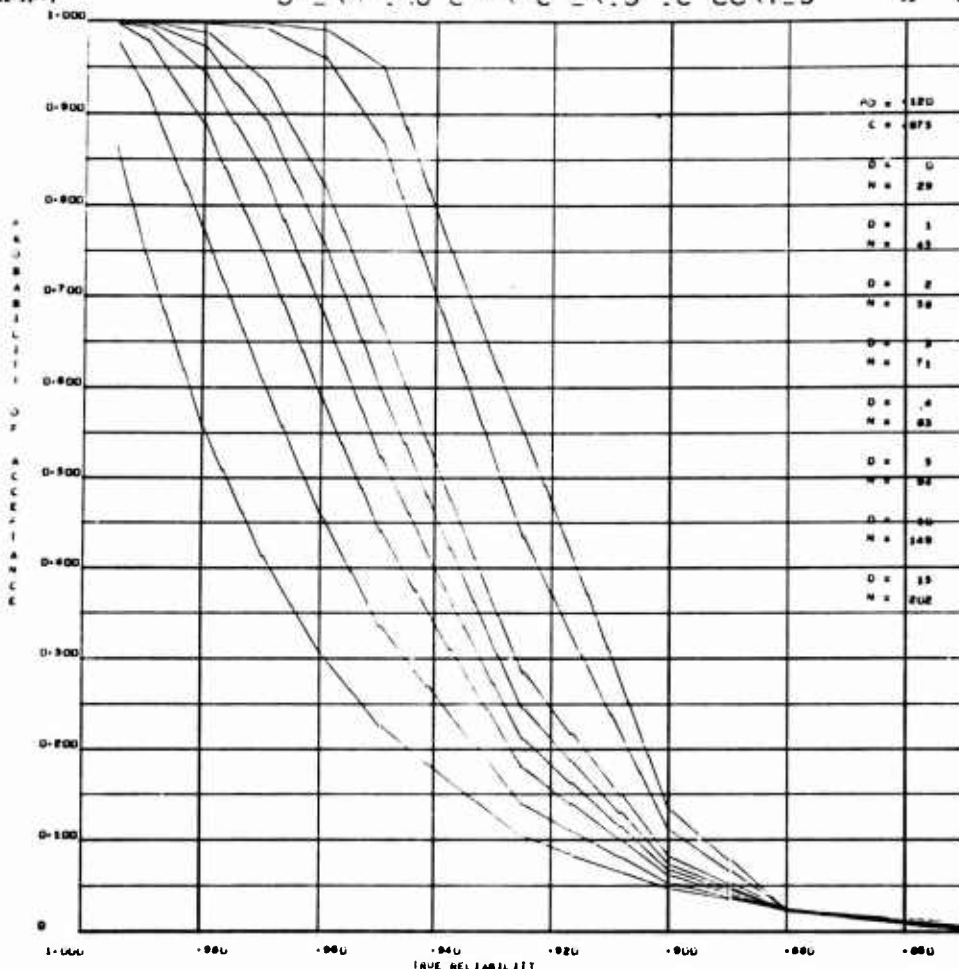


12/11/71

OPERATING CHARACTERISTIC CURVES

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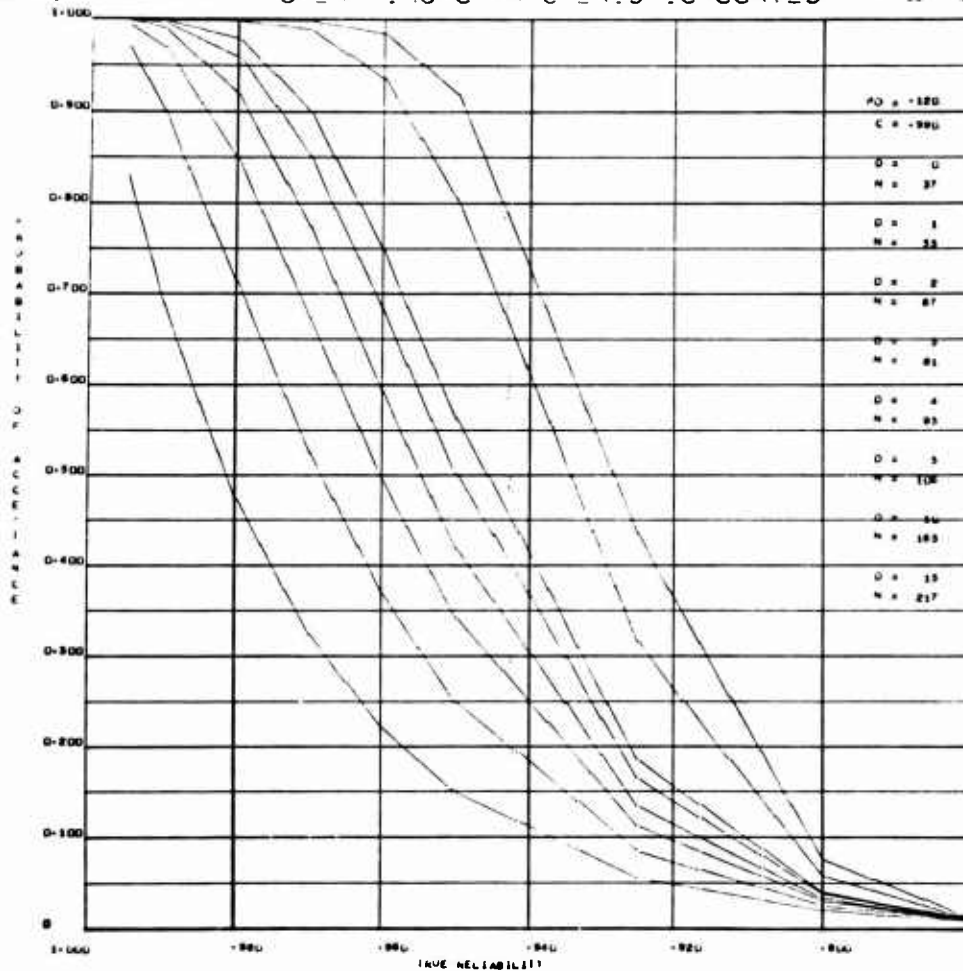
93



PL01 PREPARED BY 1641 ADIC

12/11/71

OPERATING CHARACTERISTIC CURVES

A214
34

PLOT PREPARED BY 1541 ADIC

APPENDIX XIII
OPERATING CHARACTERISTIC
CURVES ($p_0 = .130$)

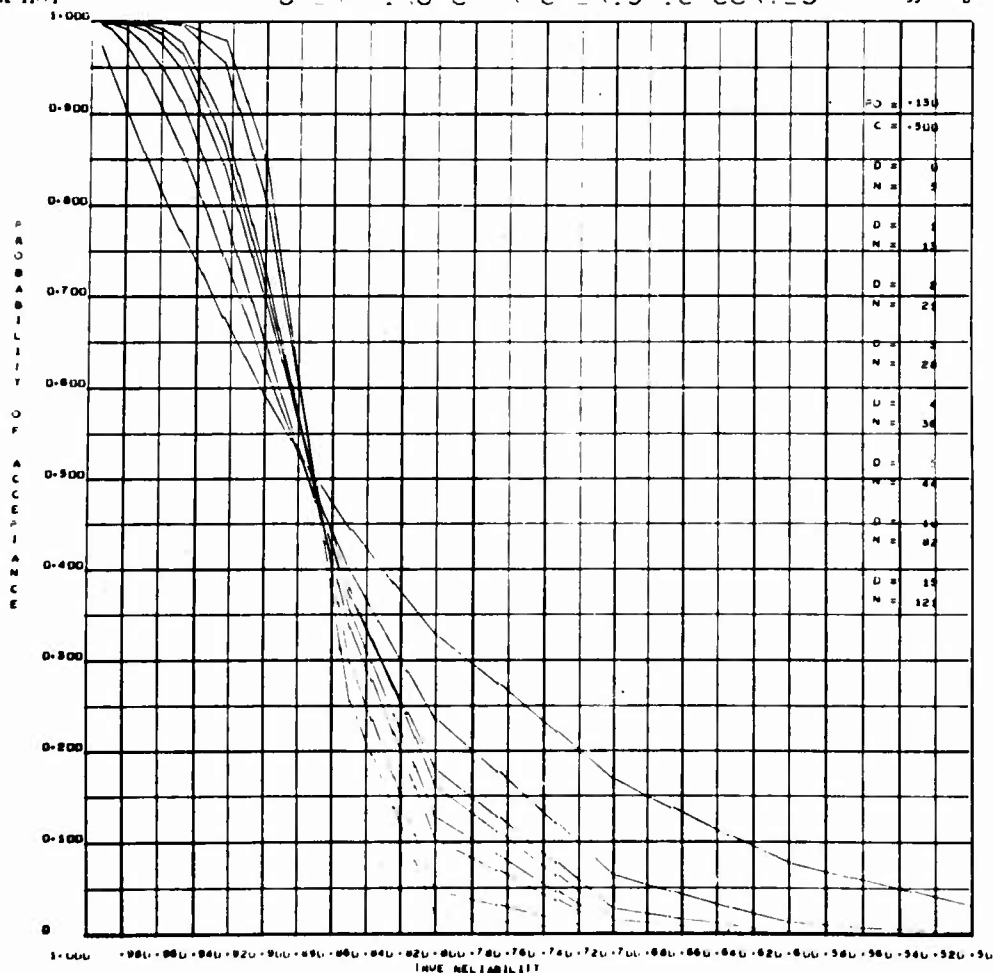
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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PLOT PREPARED BY 162, ADIC

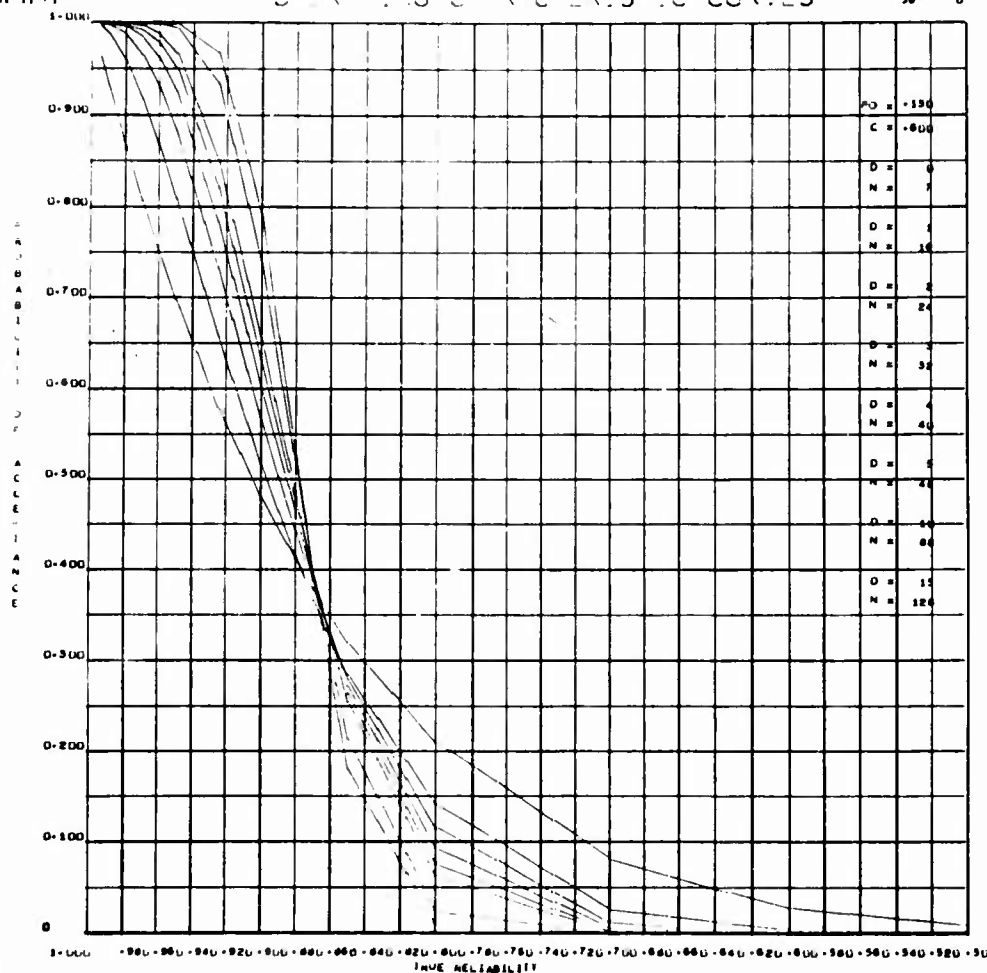
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

96

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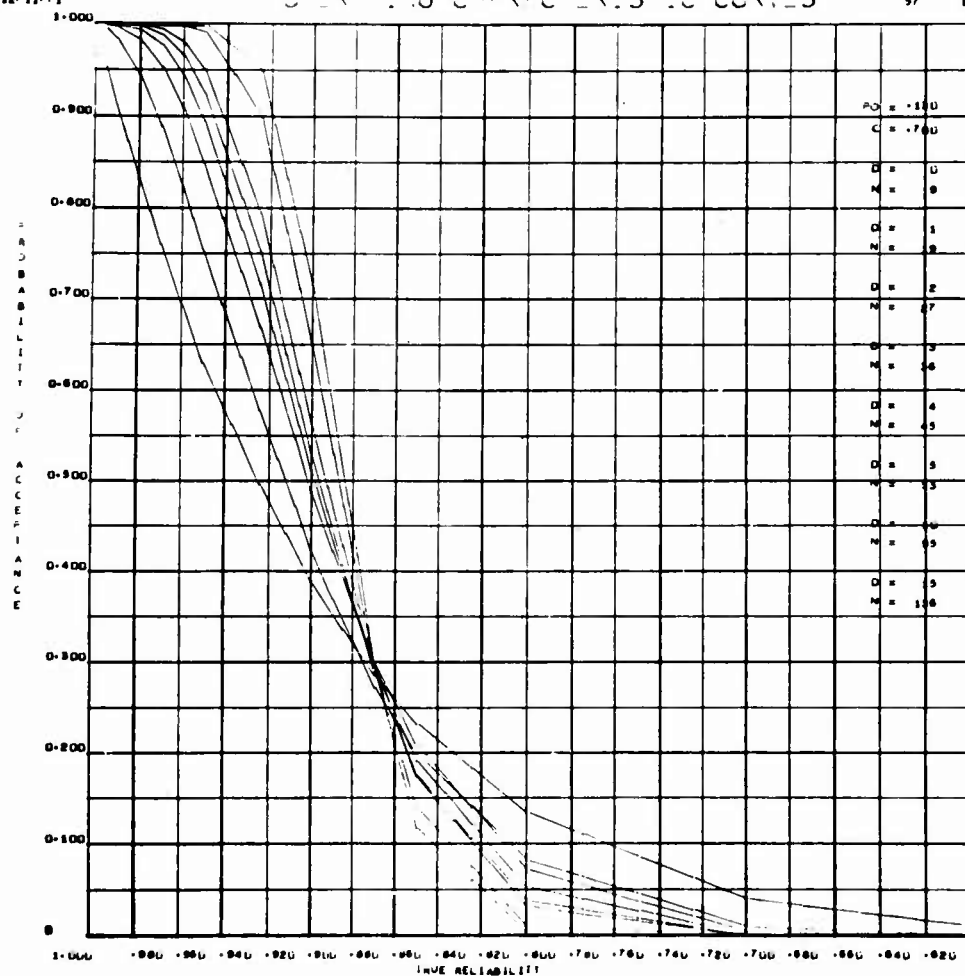
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12/11/71

OPERATING CHARACTERISTIC CURVES

A114

97



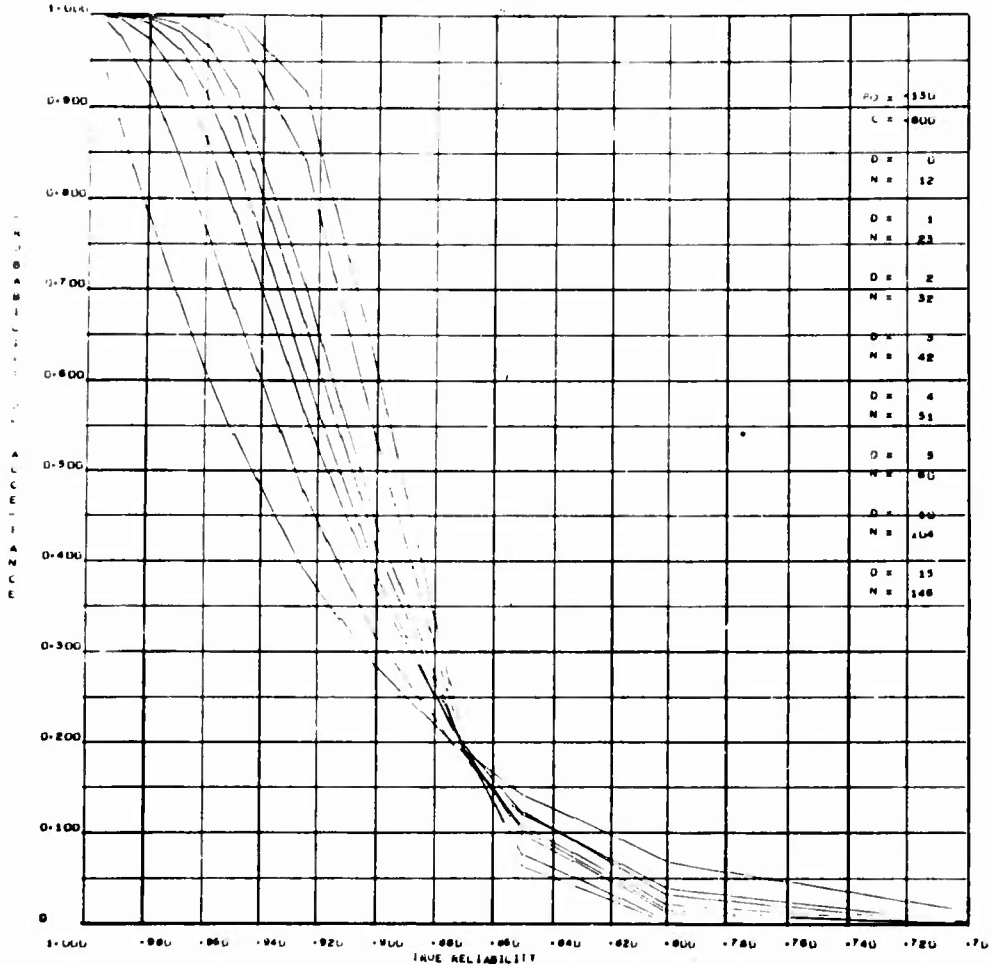
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CHARACTERISTIC CURVES

A114

96

67



NOT PREPARED BY 154 ADIC

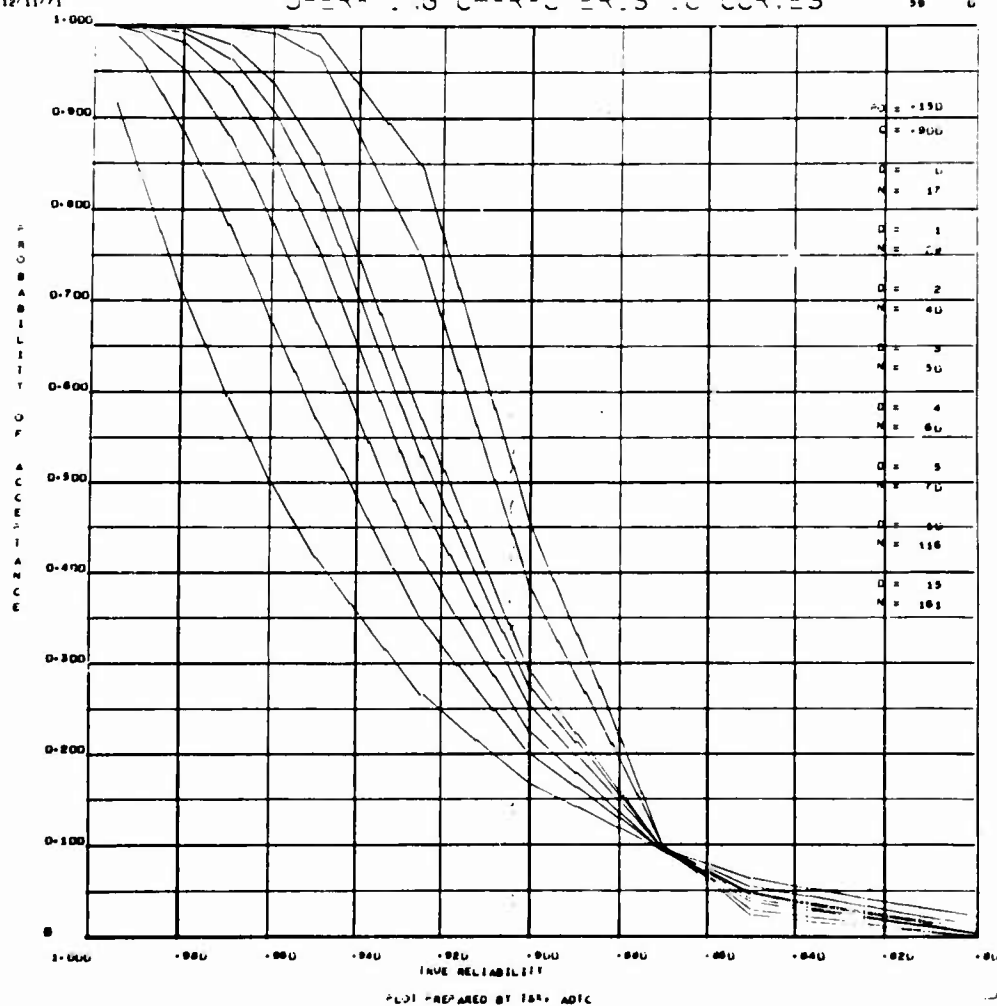
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OPERATING CHARACTERISTIC CURVES

A114

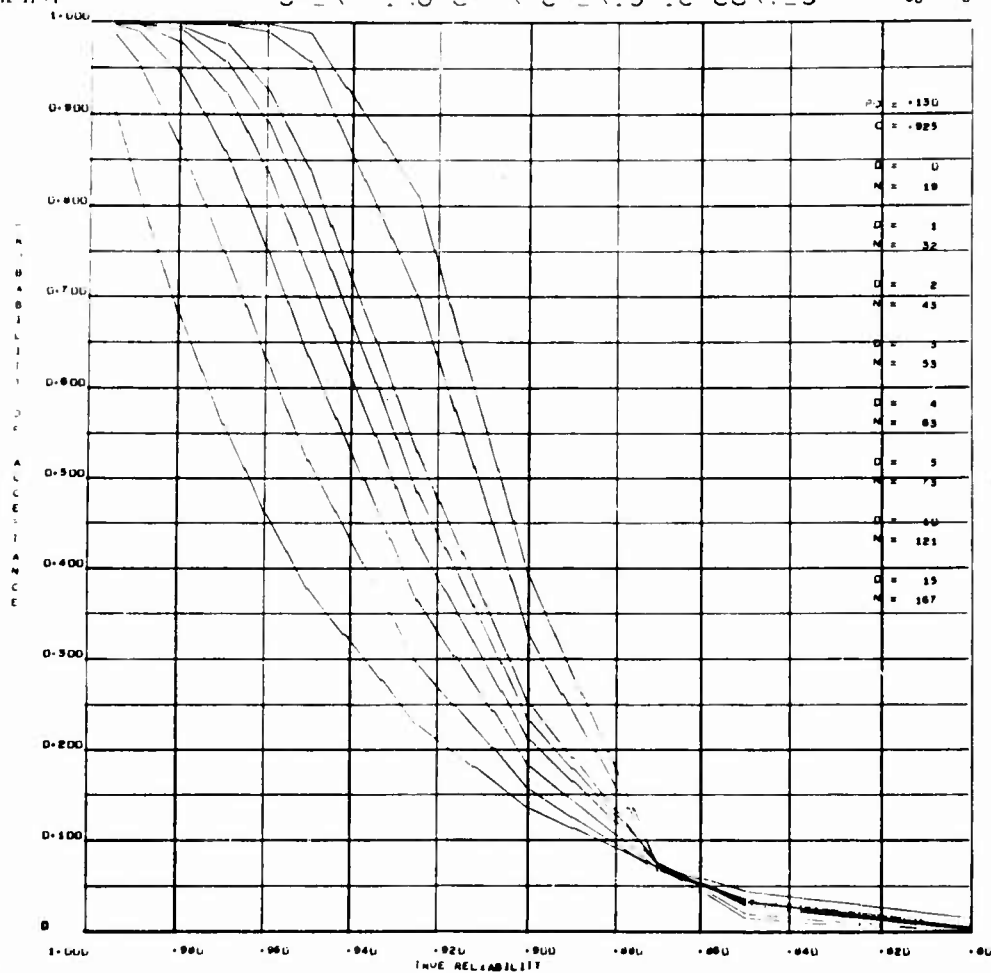
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12/11/71

OPERATING CHARACTERISTIC CURVES

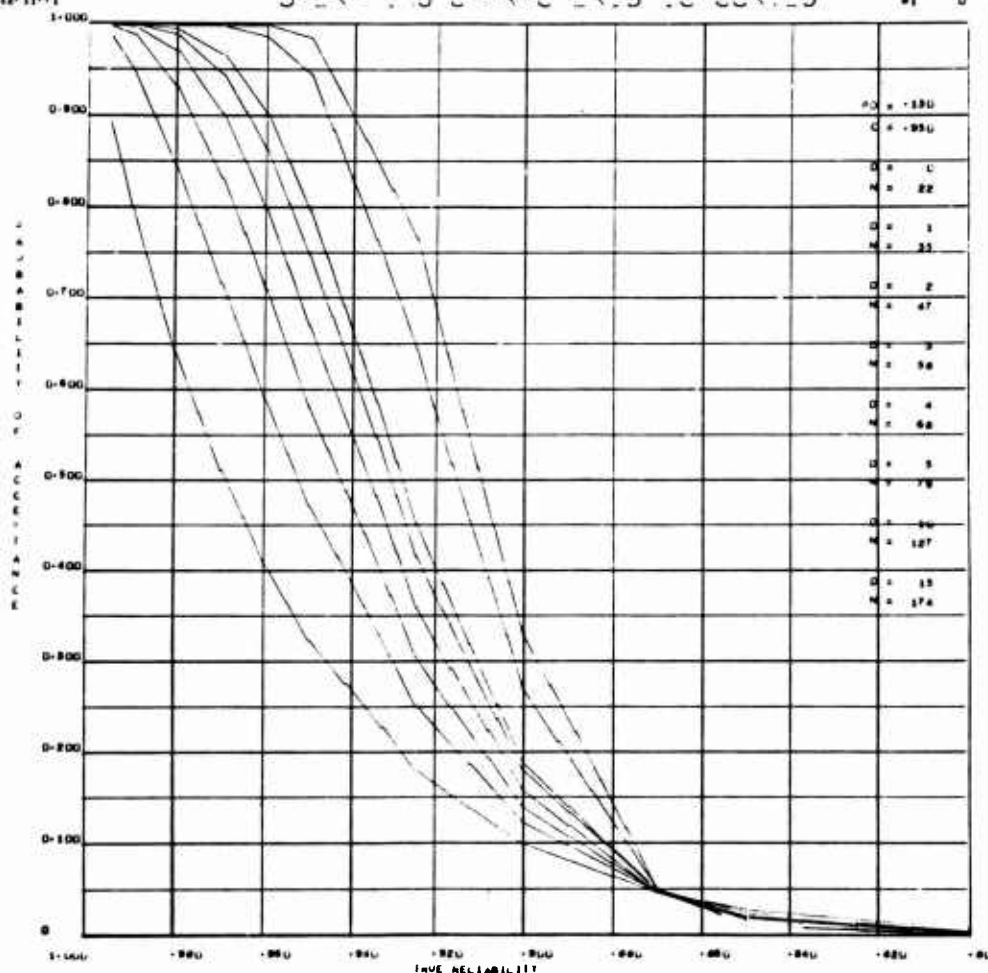
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PLOT PREPARED BY T&A: ADIC

REF 11/71

OPERATING CHARACTERISTIC CURVES

ASIA 81 07



PREPARED BY 1541 ADIC

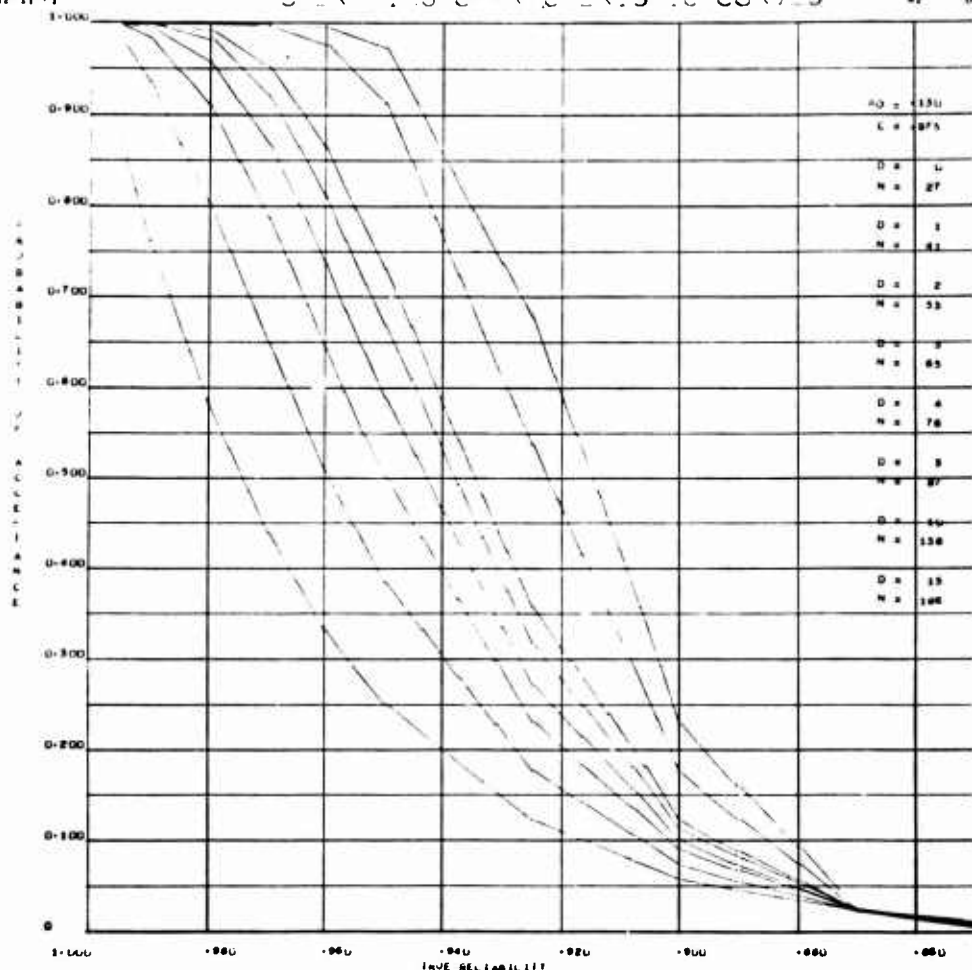
12-11-71

OPERATING CHARACTERISTIC CURVES

A114

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NOT PREPARED BY 15A, ADTC

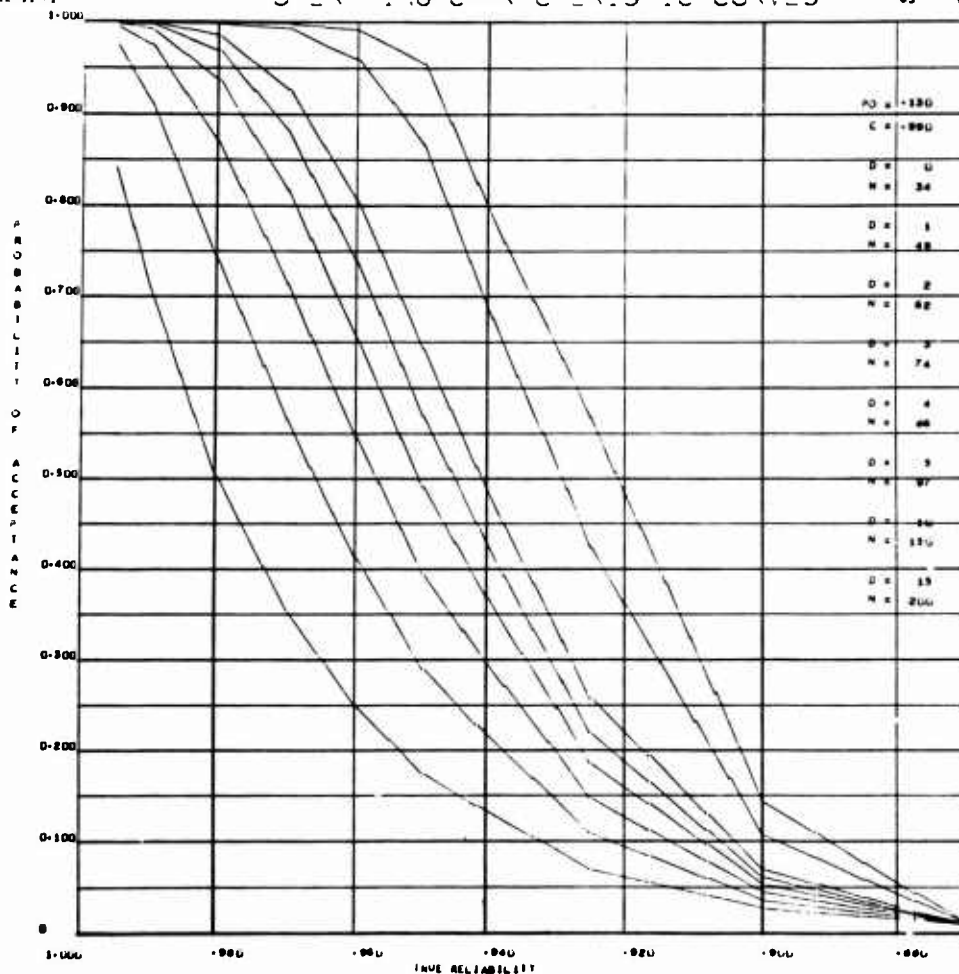
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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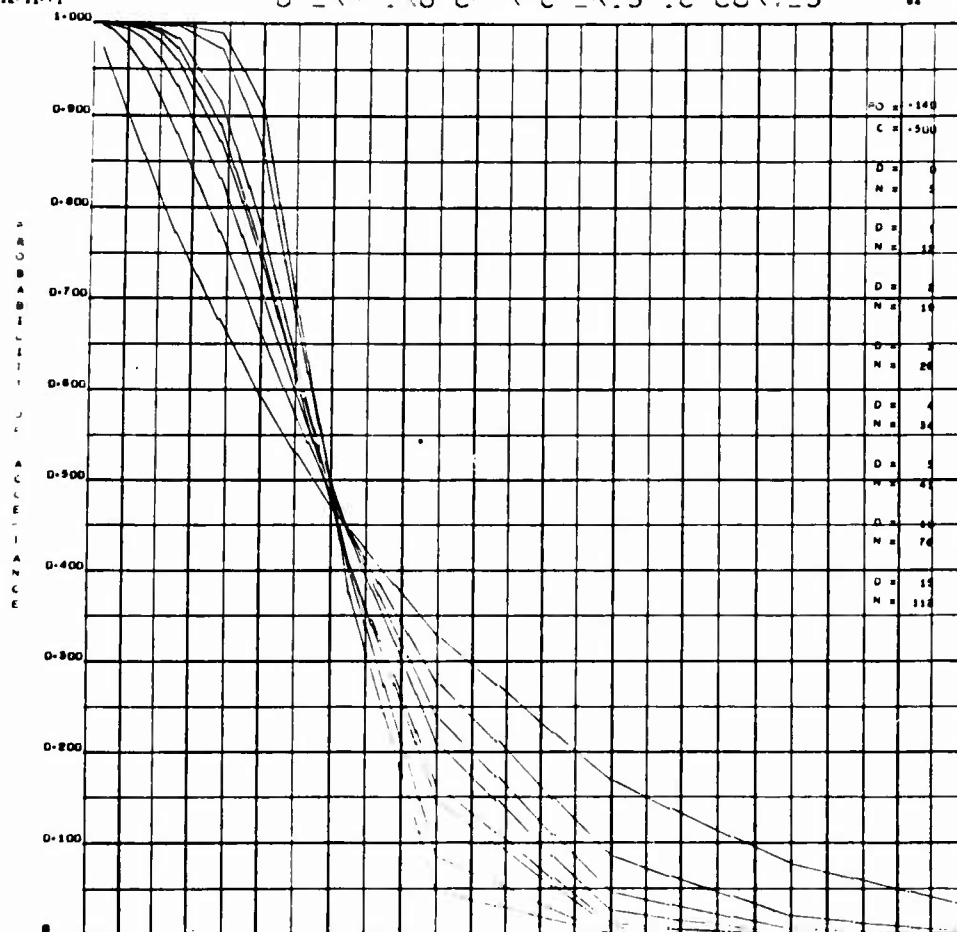
PLOT PREPARED BY TAB, ADIC

APPENDIX XIV
OPERATING CHARACTERISTIC
CURVES ($p_0 = .140$)

12/11/71

OPERATING CHARACTERISTIC CURVES

A114 64



1.000 .980 .960 .940 .920 .900 .880 .860 .840 .820 .800 .780 .760 .740 .720 .700 .680 .660 .640 .620 .600 .580 .560 .540 .520 .500

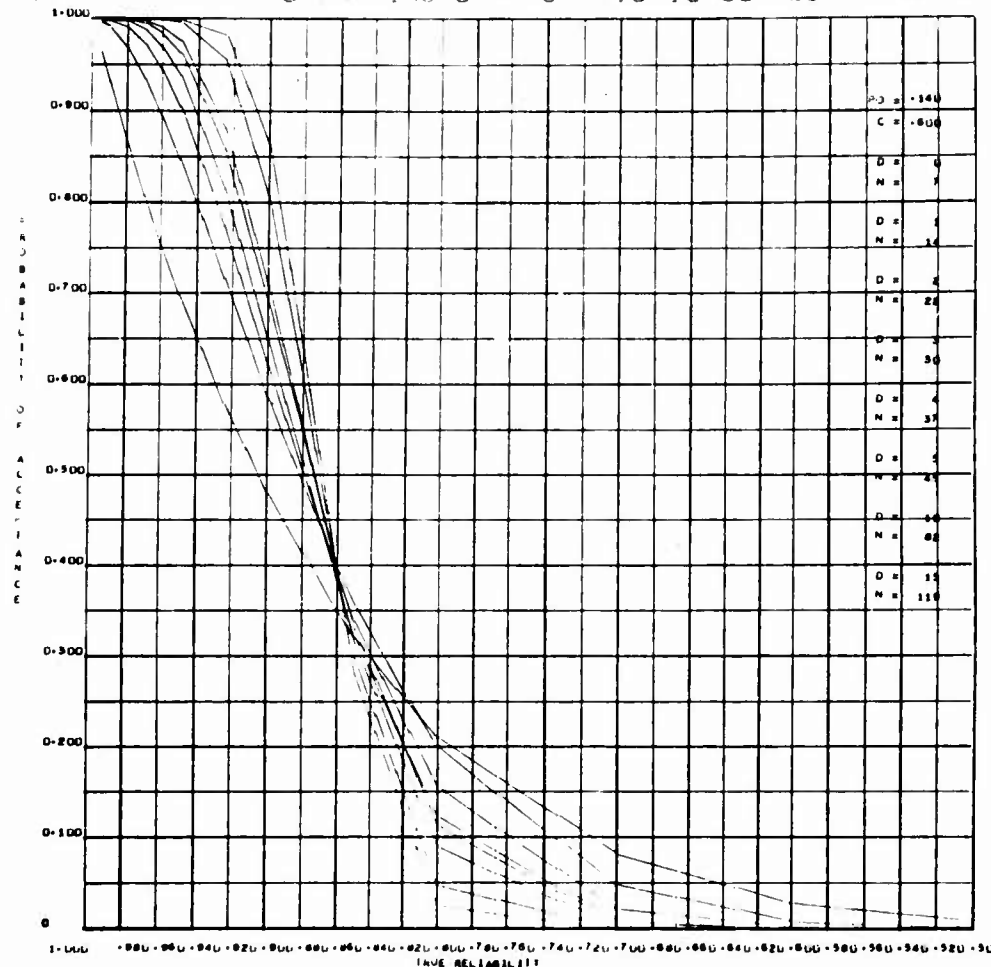
PLOT PREPARED BY 184 ADIC

12/11/71

OPERATING CHARACTERISTIC CURVES

A114

65



PLT PREPARED BY 18A ADIC

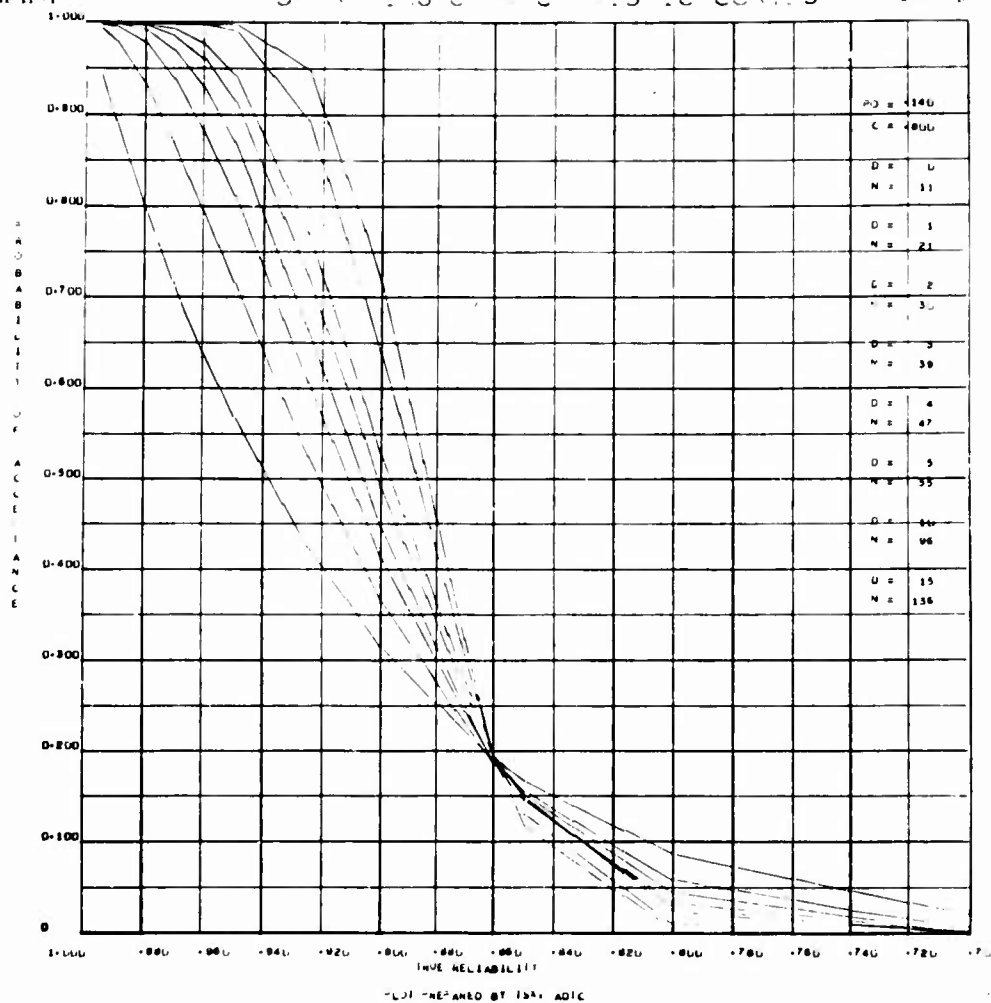
A114



12/11/71

OPERATING CHARACTERISTIC CURVES

A114 67



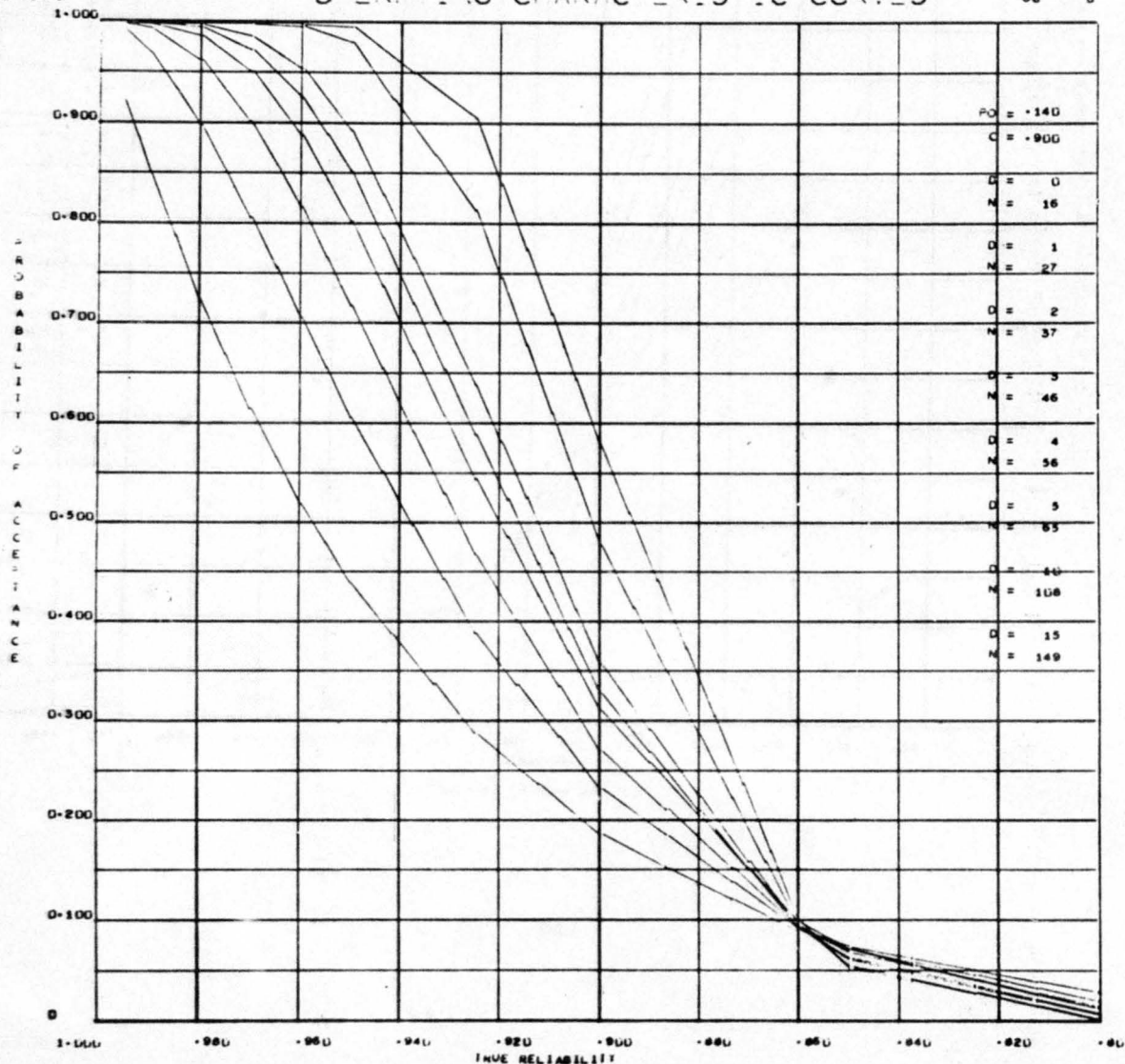
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

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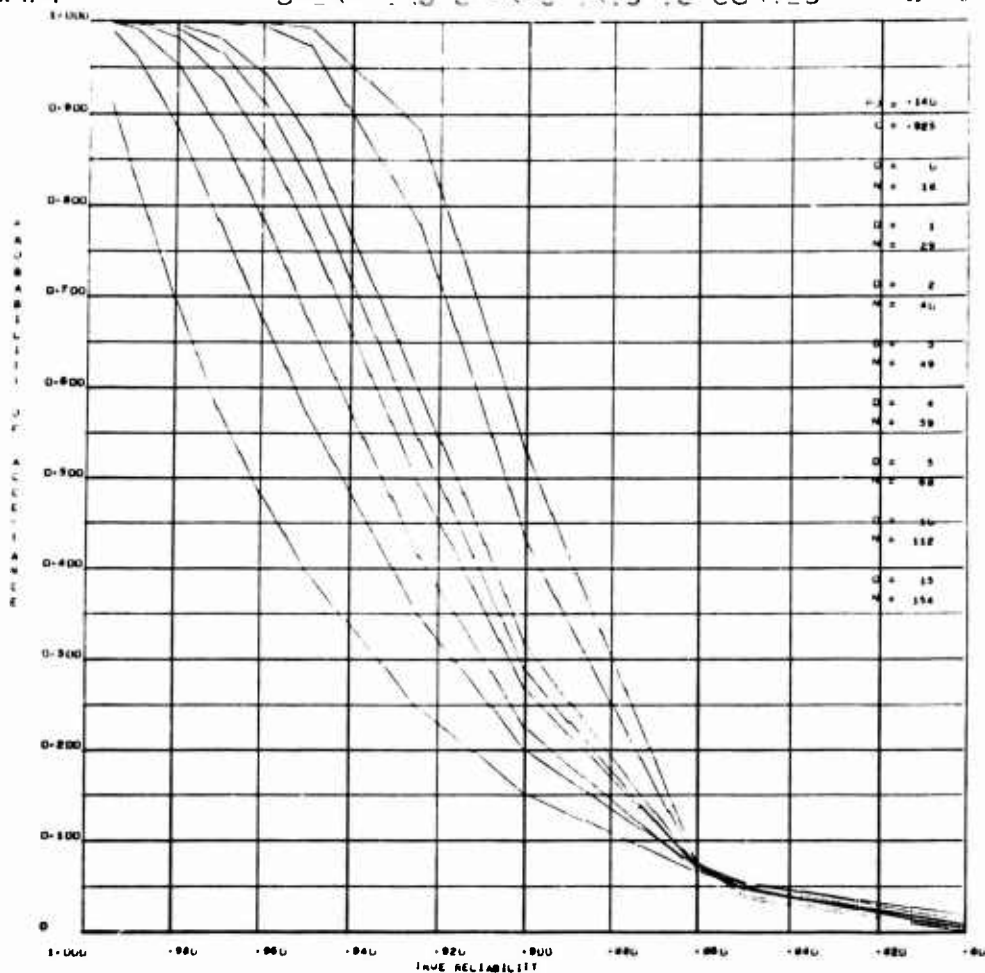


PLOT PREPARED BY TSX, ADIC

12-11-71

OPERATING CHARACTERISTIC CURVES

A314
69



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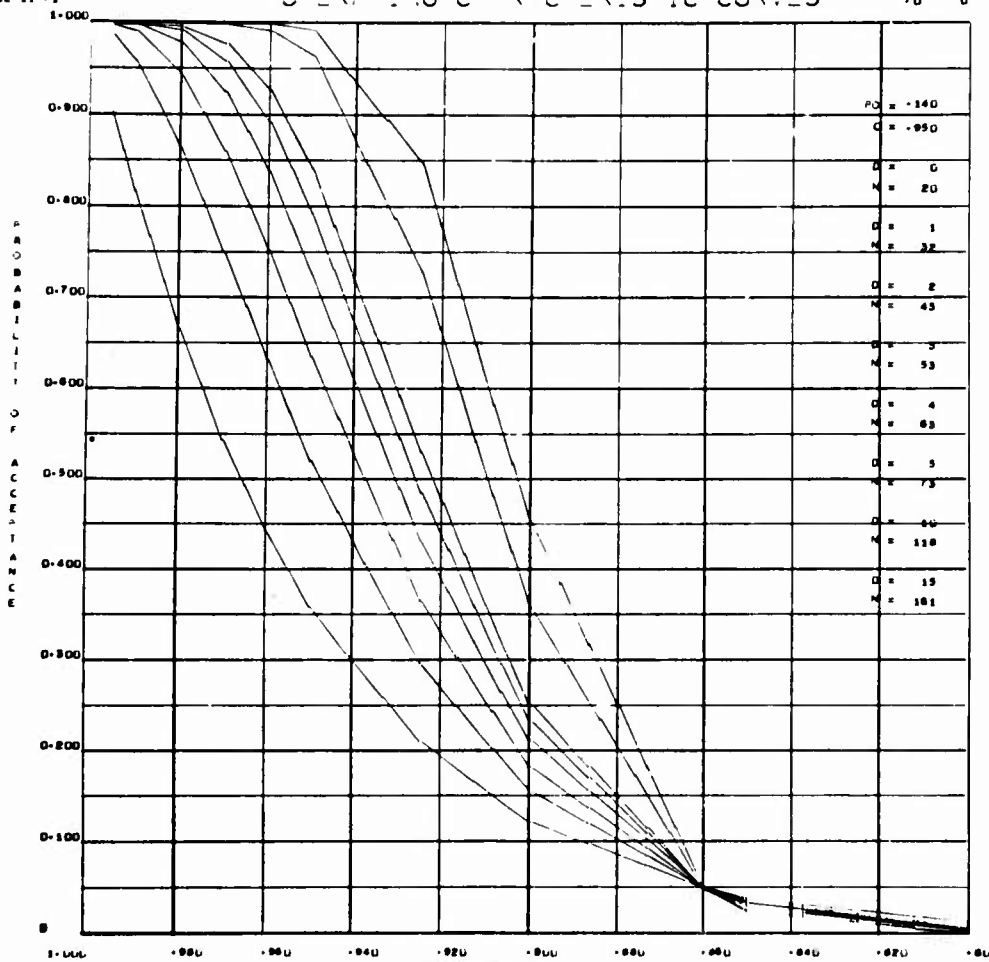
12/11/71

OPERATING CHARACTERISTIC CURVES

A114

70

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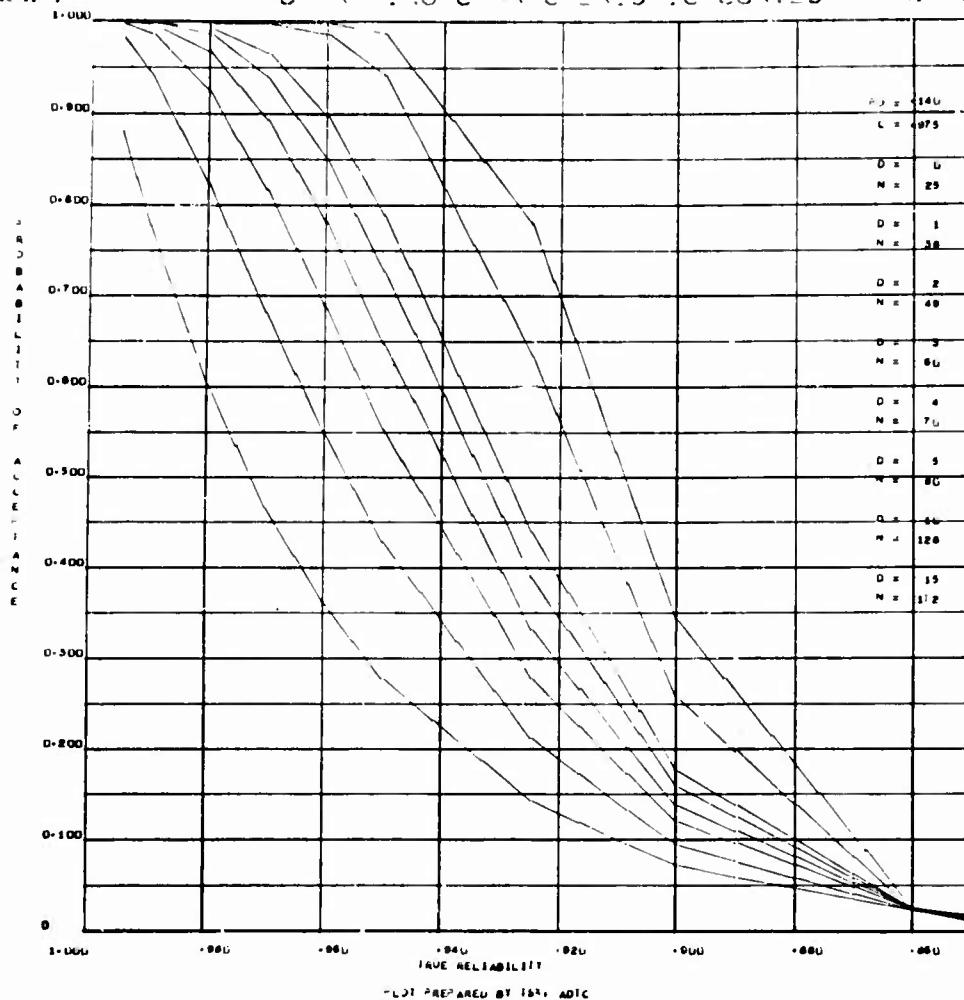
PL-31 PREPARED BY 18A, ADIC

12/11/71

OPERATING CHARACTERISTIC CURVES

A114

71 U

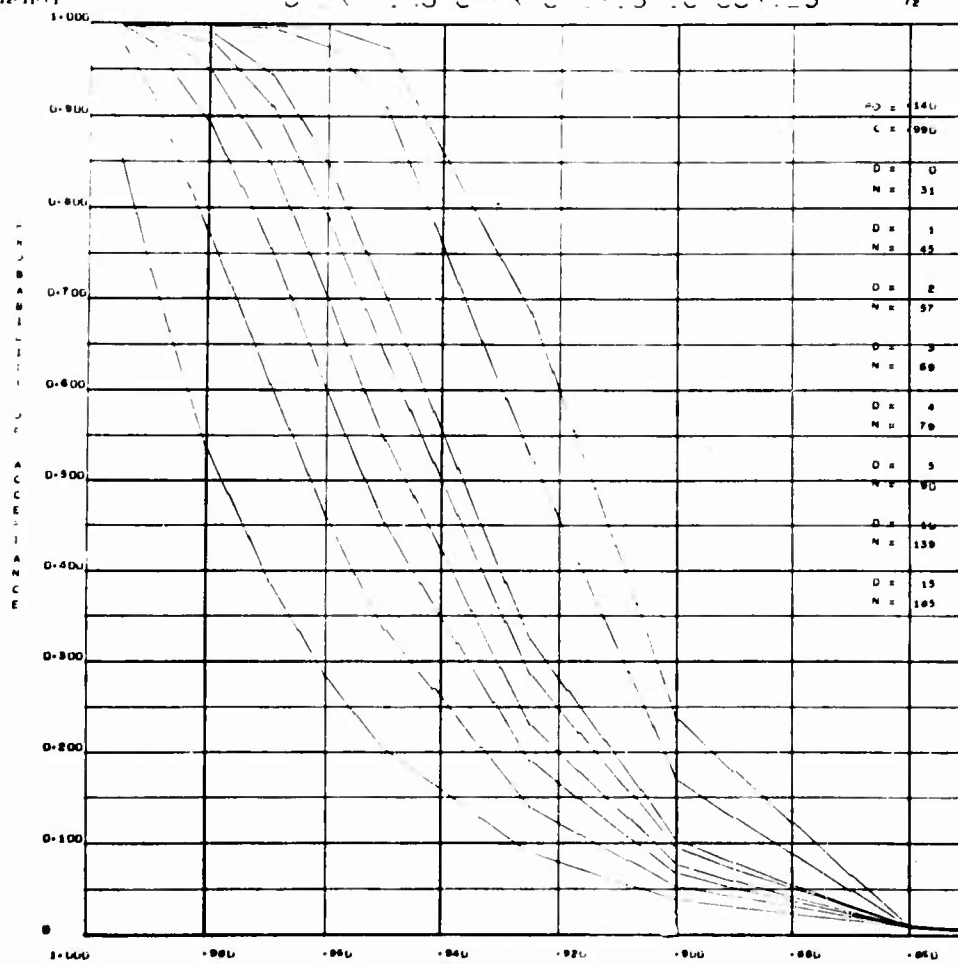


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OPERATING CHARACTERISTIC CURVES

A114
72

67



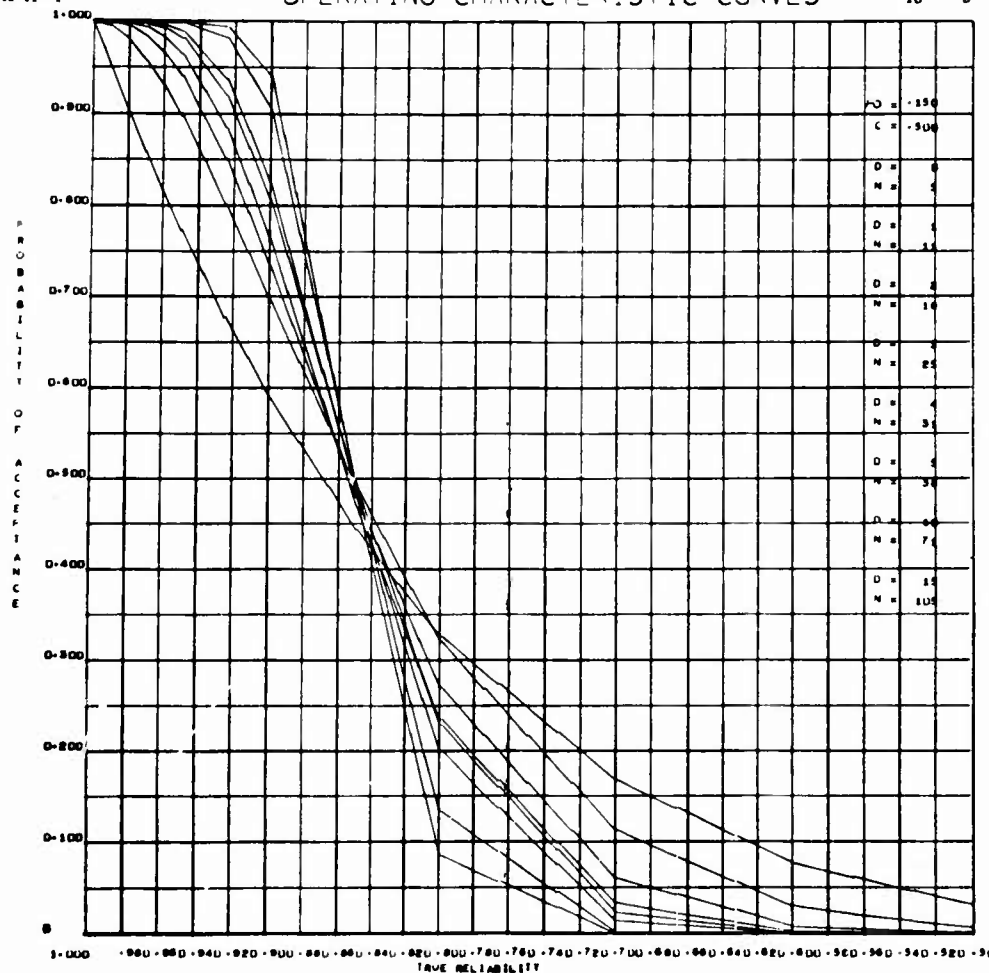
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APPENDIX XV
OPERATING CHARACTERISTIC
CURVES ($p_0 = .150$)

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OPERATING CHARACTERISTIC CURVES

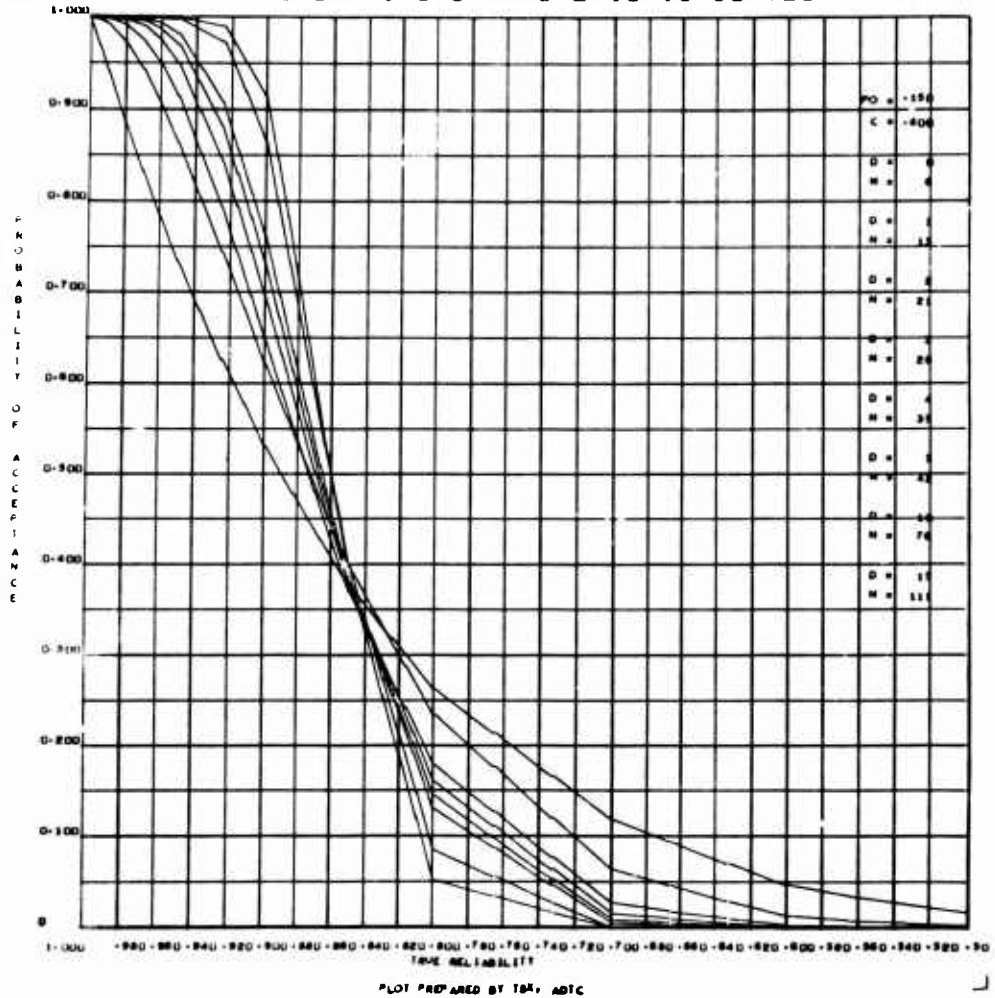
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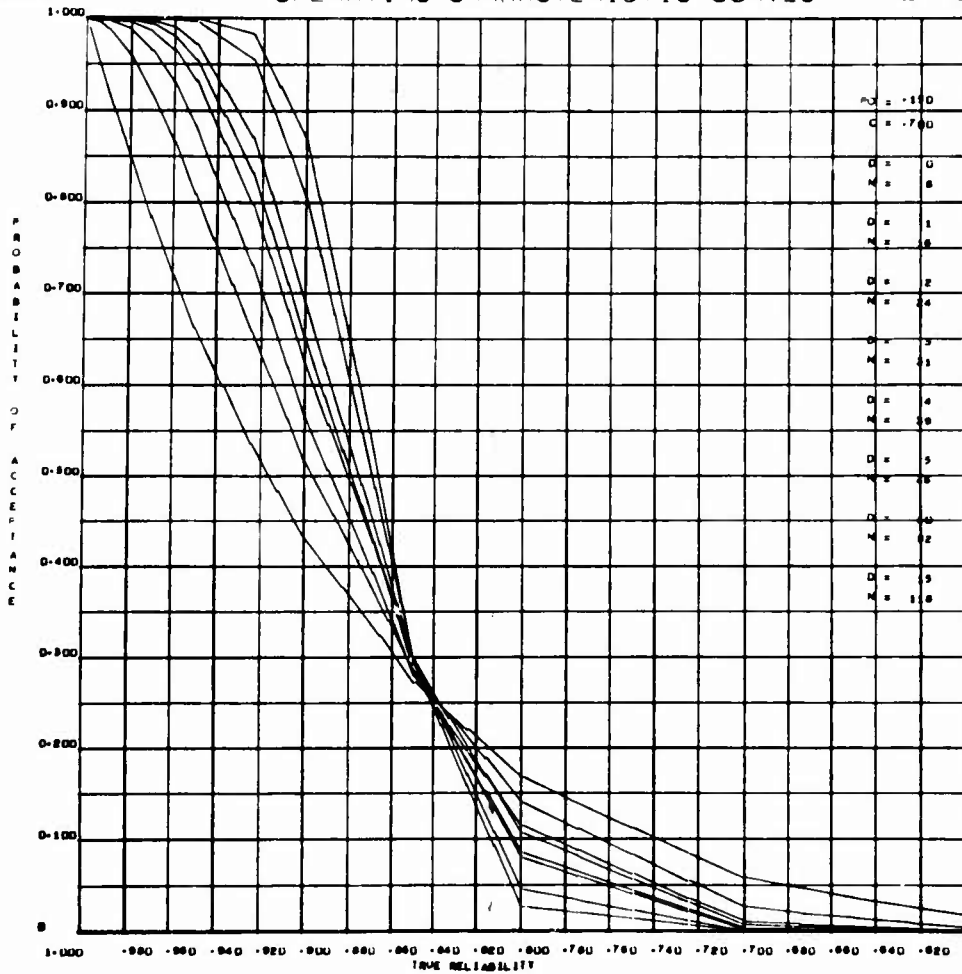
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OPERATING CHARACTERISTIC CURVES

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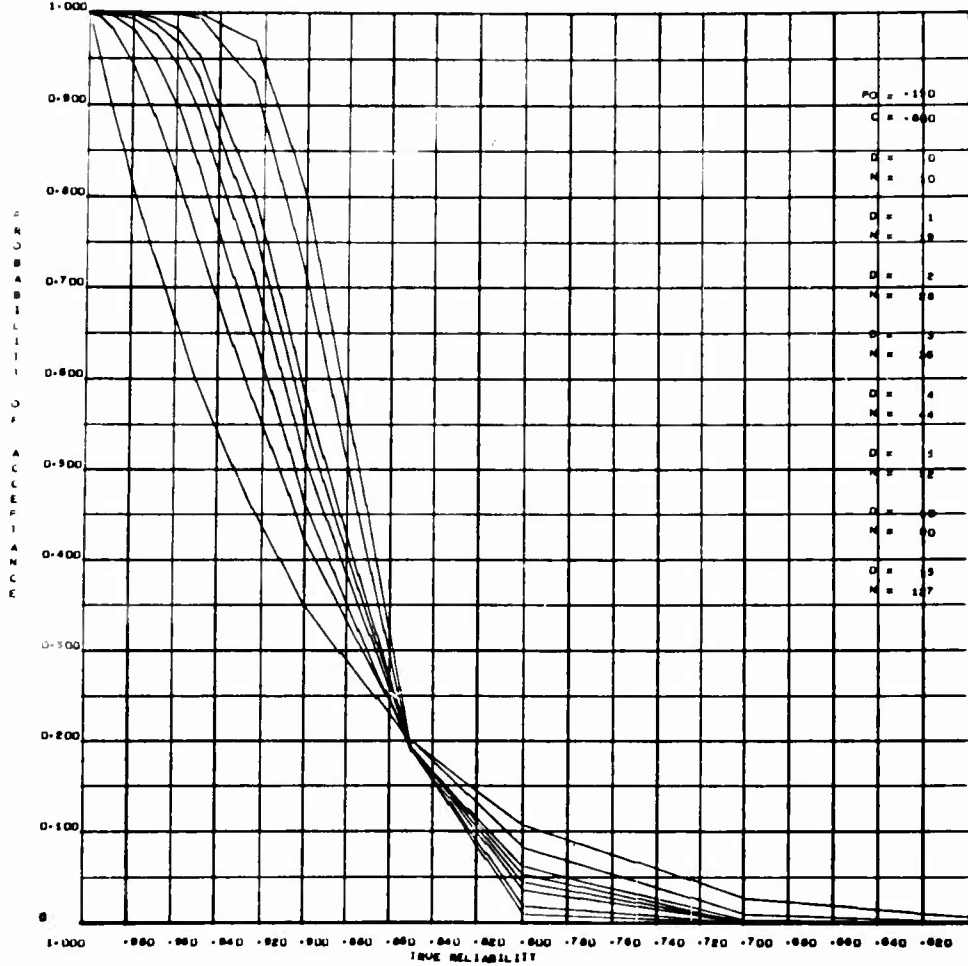


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OPERATING CHARACTERISTIC CURVES

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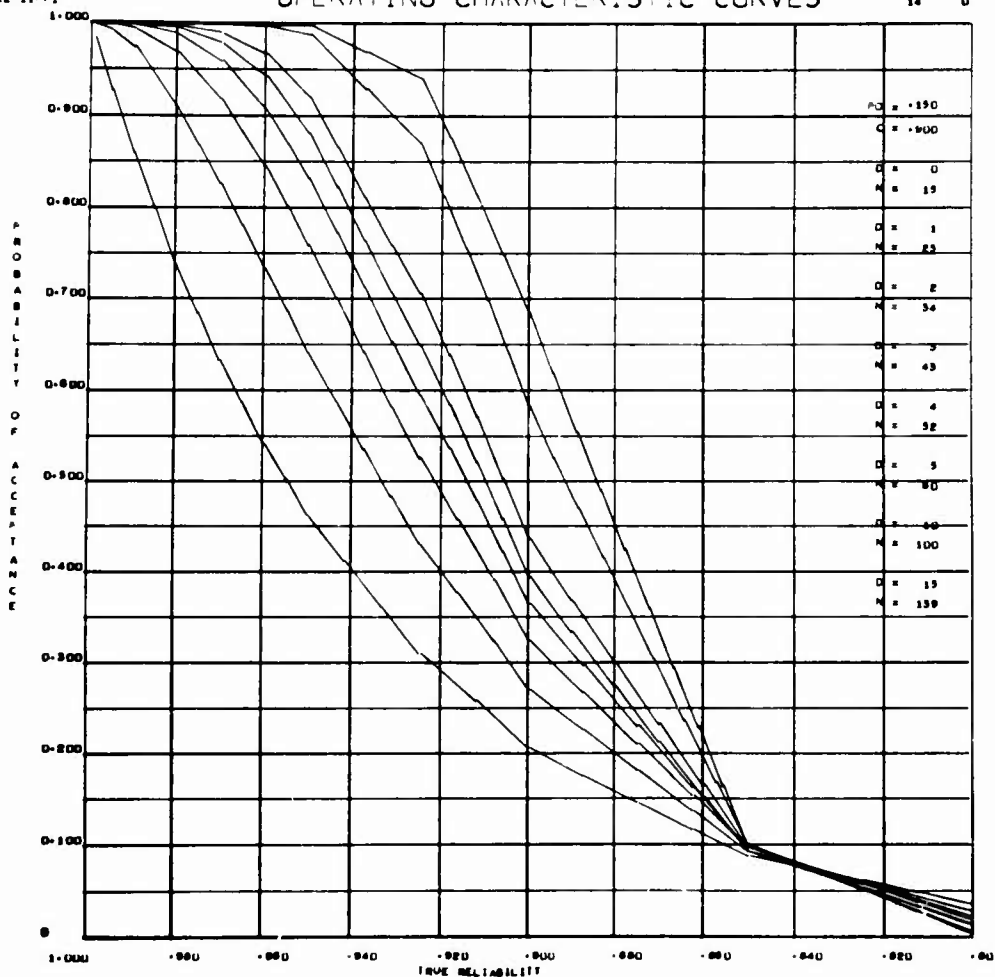


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OPERATING CHARACTERISTIC CURVES

A10E
14

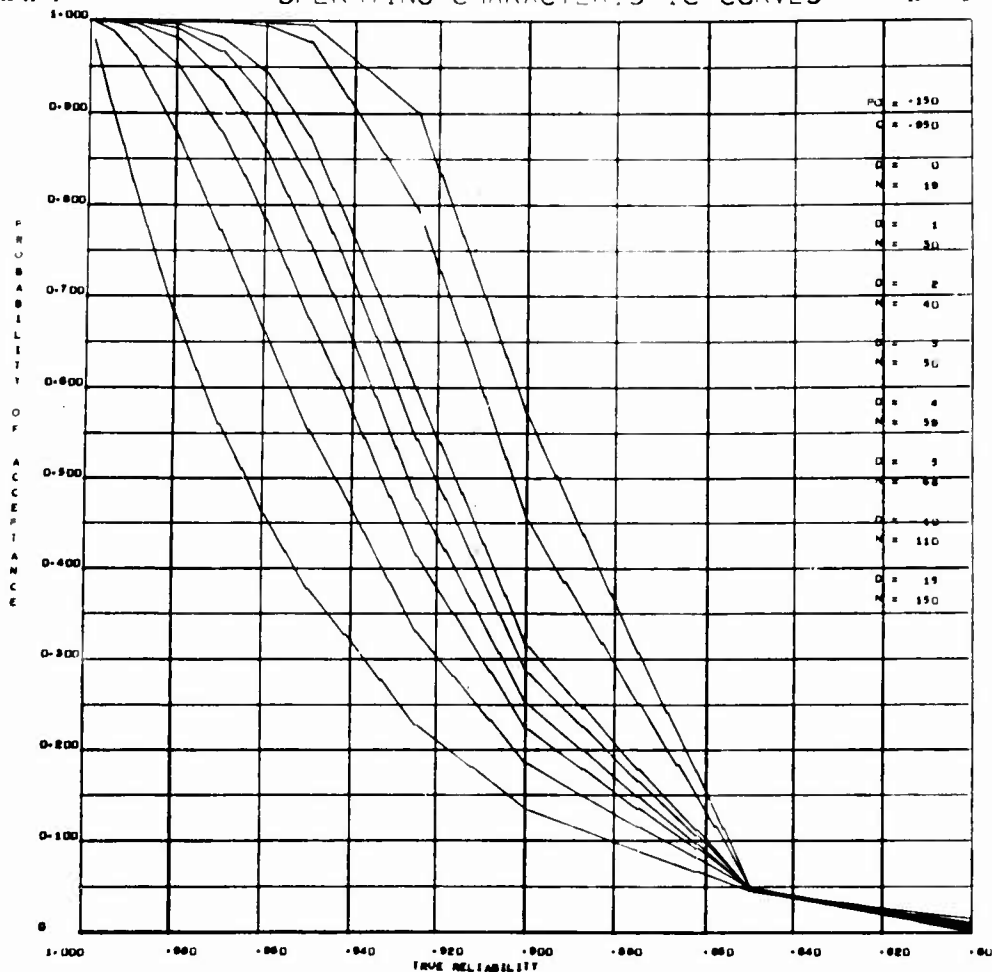


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OPERATING CHARACTERISTIC CURVES

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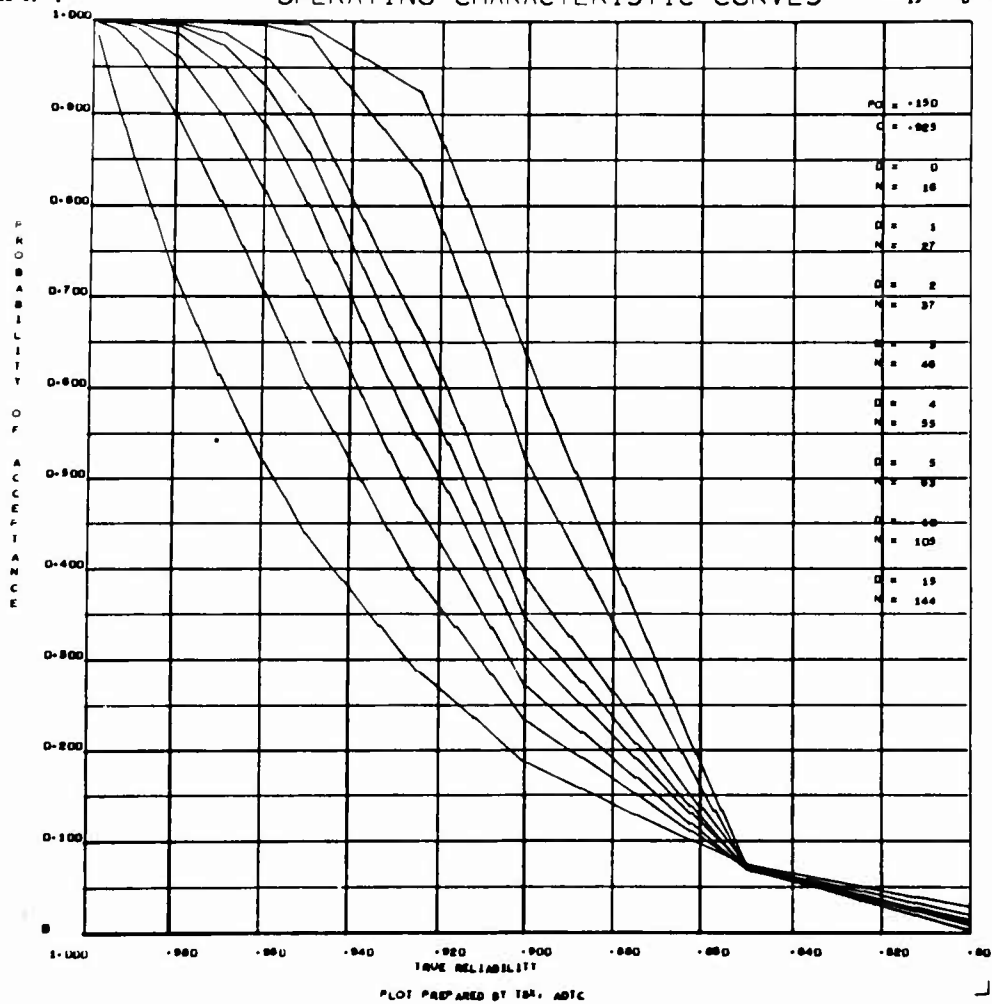


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12/11/71

OPERATING CHARACTERISTIC CURVES

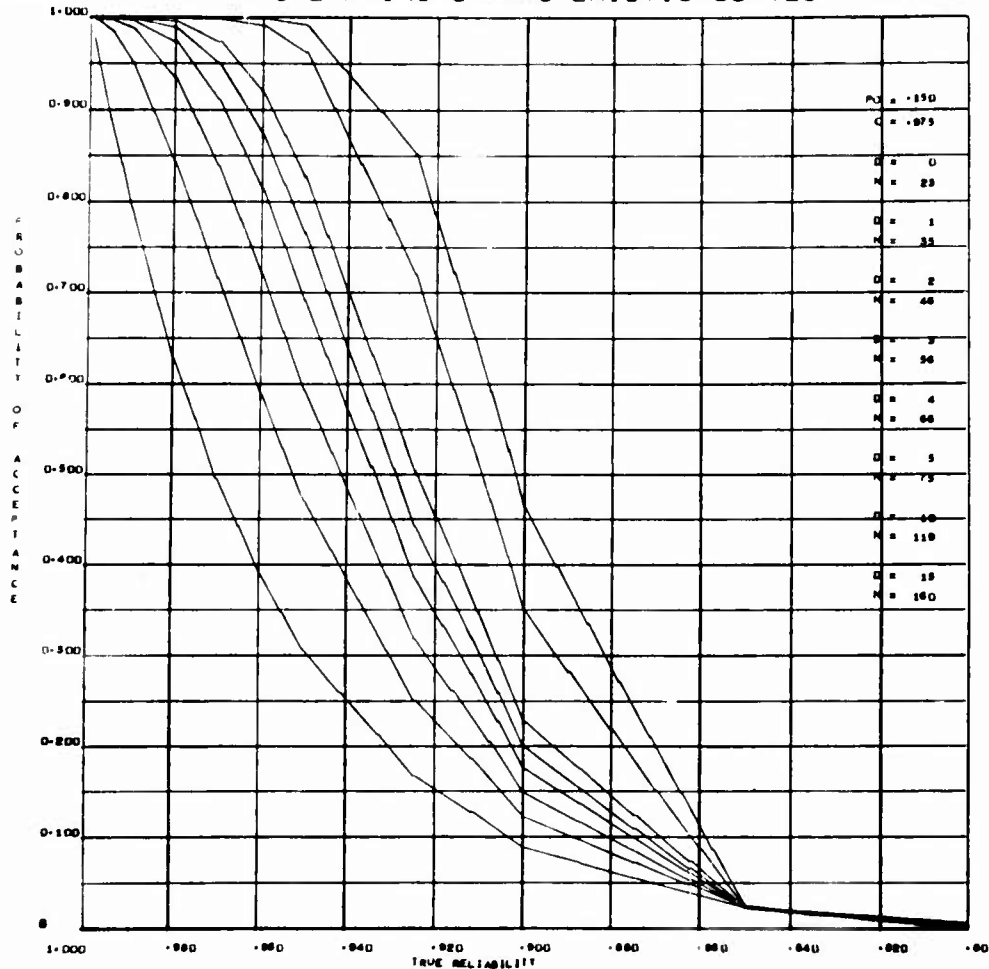
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OPERATING CHARACTERISTIC CURVES

A108
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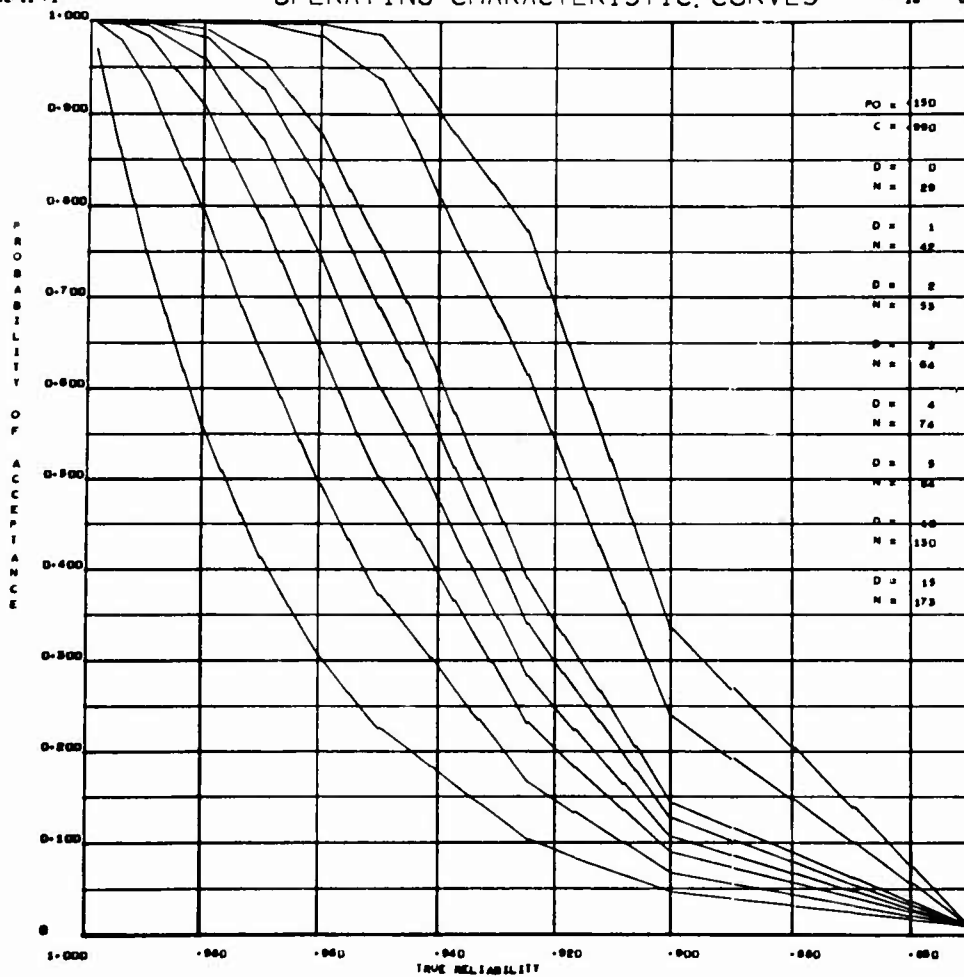


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A102 10 0



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| 13. ABSTRACT Operating characteristic curves are presented which give the probability of a random sample from a binomial population being accepted versus the true reliability of the lot for a given sample size and with the acceptance number of defectives held fast. The curves can be used by statisticians, engineers, and quality assurance workers concerned with attributes testing of large lots of items submitted for testing or with writing specifications for such tests. | | | |

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